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# PANAMA DISEASE OF BANANAS.

## REPORTS ON SCIENTIFIC VISITS TO THE BANANA GROWING COUNTRIES OF THE WEST INDIES, CENTRAL AND SOUTH AMERICA

By

CLAUDE W. WARDLAW, Ph.D., D.Sc., F.R.S.E.
Pathologist for Banana Research at the Imperial College of Tropical Agriculture, Trinidad,

and

LAURENCE P. McGUIRE, Ph.D., M.Sc., D.I.C.
Physiologist for Banana Research at the Imperial College of Tropical Agriculture, Trinidad.

E·M·B

JULY, 1929

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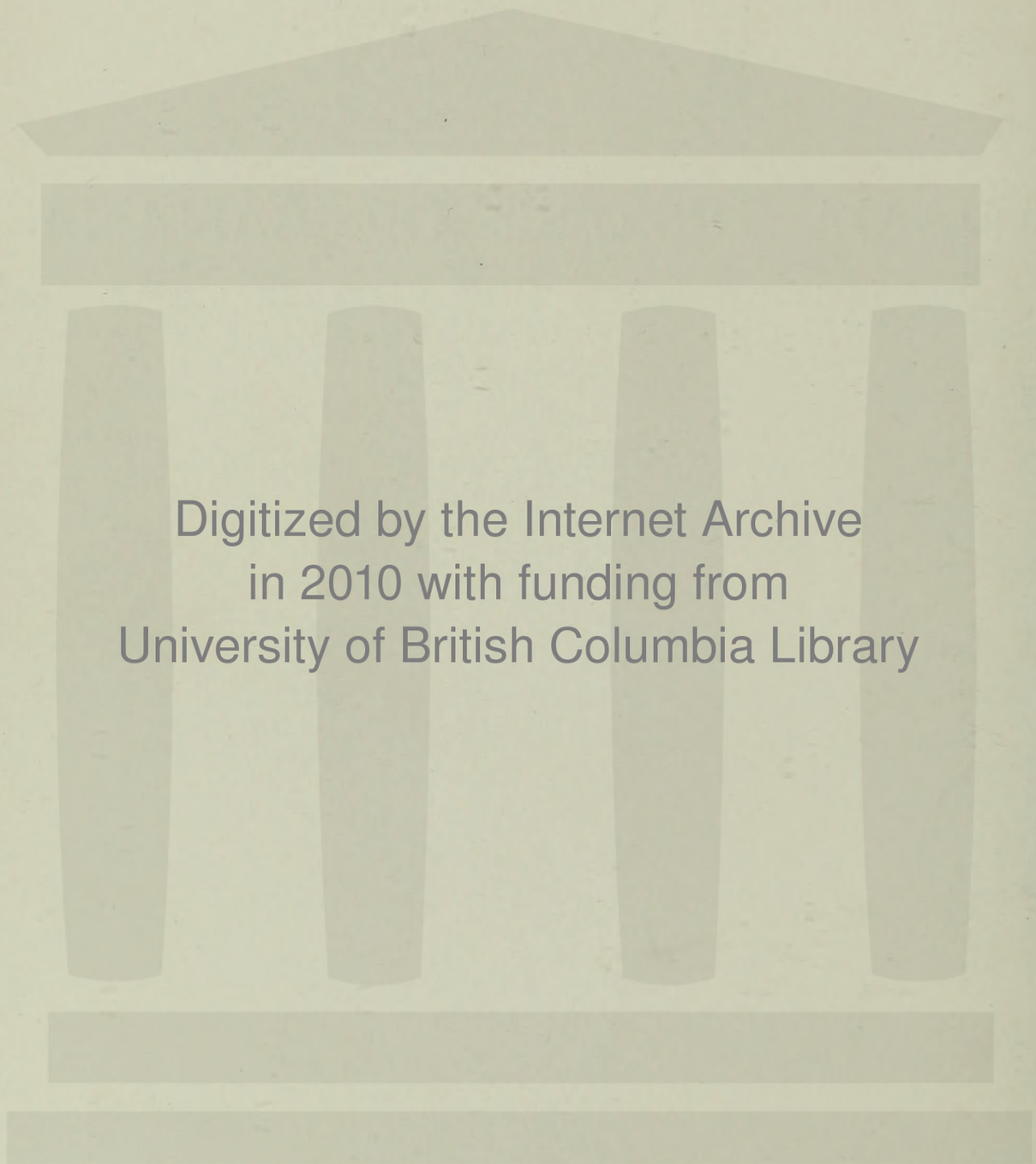
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# THE IMPERIAL COLLEGE OF TROPICAL AGRICULTURE.

*Incorporated by Royal Charter.*

*Patron :*
HIS MAJESTY THE KING.

The objects of the Imperial College of Tropical Agriculture, which was founded in 1921, are to provide training in the science and practice of tropical agriculture to students intending to become tropical planters, agricultural administrators or officers, or specialists in different branches of agricultural science and technology, and to offer facilities for the study of tropical agriculture to graduates of other colleges and universities.

An important feature of the College is the provision for research and investigation work which its laboratories and fields afford.

The College Buildings and Laboratories are situated in spacious grounds at St. Augustine, seven miles to the eastward of Port of Spain, Trinidad. Easy access to them is afforded by the Government Railway and the Eastern Main Road, both of which pass the College.

The College is controlled by a Governing Body of which the Chairman is Sir James Currie, K.B.E., C.M.G., and the Vice-Chairman Sir David Prain, C.M.G., C.I.E., LL.D., F.R.S.

The Principal is Mr. Geoffrey Evans, C.I.E., M.A., Dip. Agr., who is assisted by a staff of 9 Professors and 7 Lecturers.

By arrangement with the Empire Marketing Board and with the co-operation of the Royal Botanic Gardens, Kew, and the Low Temperature Research Stations at Cambridge, long range research in connection with bananas is being conducted by the Imperial College at St. Augustine.

Particulars regarding the College and its work can be obtained from the Secretary, Sir Algernon Aspinall, C.M.G., C.B.E., 14, Trinity Square, London, E.C.3.

# PREFACE.

In 1903 a destructive plague appeared among the promising banana plantations of Panama ; and large areas, both in that country and in Costa Rica were soon abandoned by their cultivators. This disease, known as Panama Disease, has spread to other Caribbean lands and is a persistent menace to the banana crop there.

The rapid spread of Panama Disease and the heavy losses resulting from it formed one of the problems which had to be considered by the Imperial Economic Committee when their Report on Fruit was being prepared in 1926. The staff of the Royal Botanic Gardens, Kew, were already at work on the search for a variety of banana which, while retaining the economic advantages of the Gros Michel usually grown in the British West Indies, should be immune to the dreaded Panama Disease. The Imperial Economic Committee recommended that these researches should be pushed forward, and that financial assistance should be given to that end.

Acting on this recommendation the Empire Marketing Board has made grants to the Imperial College of Tropical Agriculture, Trinidad, and to the Royal Botanic Gardens, Kew, for research into the production of a banana plant immune to Panama Disease and for investigation into the transport of bananas under cold storage conditions.

An investigator from Kew has been at work in the East, the original home of the banana, searching for varieties which might develop the desired qualities ; and some promising finds have been made. It is necessary, however, to proceed with the utmost caution. These promising varieties cannot be introduced into the West Indies without a period of quarantine, for fear of introducing diseases common to bananas in oriental countries more serious than Panama Disease itself. The specimens are, therefore, brought to a quarantine house at Kew for testing and propagation, pending their despatch to the West Indies.

Meanwhile the Imperial College of Tropical Agriculture is studying the disease itself and the best means of combating it. It has for some time been thought that the multiplication and spread of *Fusarium cubense,* the organism responsible for Panama Disease, is closely connected with lack of fertility and with adverse soil conditions. Dr. Claude W. Wardlaw, the Pathologist for Banana Research

attached to the Imperial College of Tropical Agriculture, has made a tour of the banana producing countries in the Caribbean area, and has investigated the conditions which have led to the abandonment of plantations. In particular, he has examined the conditions in which Panama Disease has been prevalent. His Report gives an account of his observations in that field, and indicates the conclusions suggested by the survey.

The Report by Dr. Laurence P. McGuire, Physiologist for Banana Research at the Imperial College, emphasises in a striking way the conclusions arrived at by Dr. Wardlaw as a result of his tour. The cause of abandonment of banana lands in the areas visited is not, it is stated, solely due to the ravages of Panama Disease. Other factors such as unsuitable soils, high cost of management, water logging, and the like also contribute. On the other hand Dr. McGuire confirms the observations previously arrived at by officers of the Imperial College in the course of their experiments to the effect that certain varieties possess considerable powers of resistance to Panama Disease.

WALTER ELLIOT,

*Chairman of the Research Grants Committee.*

Empire Marketing Board,

May, 1929.

THE IMPERIAL COLLEGE OF TROPICAL AGRICULTURE,

TRINIDAD.

*24th November*, 1928.

To The Empire Marketing Board.

Gentlemen,

This report gives an account of my visits to Barbados, St. Lucia, Costa Rica, Guatemala, British Honduras, Jamaica, Colombia, and Panama. The information conveyed here is necessarily selective, and only data germane to the subjects of banana cultivation, disease, or abandonment have been submitted. Where information can already be obtained in published form, as in the case of Jamaica, the report is brief, but where accurate accounts have not hitherto been available, the observations are set out in greater detail. I shall be glad to discuss other aspects of the subject if desired.

Panama Disease is an investigation of great complexity, not only on mycological grounds, but also because it is closely interwoven with the many unexplored problems relating to the deterioration of virgin soils. Thus my visits to Central America have shown clearly that Panama Disease is not necessarily the only, or in all cases, the principal factor for large scale abandonment. Other factors such as choice of land, inadequate soil exploration, drainage, supply of planting material, etc., are also important, but in the primitive state of agriculture in a new country, the tendency is to assign all failures to any important contemporary disease. Thus in the absence of a personal visit, one would be greatly misled by the information in current circulation.

These several visits have served to indicate that the problem is of great scientific interest, and that its solution will call for detailed pathological and physiological studies, together with careful observations on the behaviour of virgin soils under intensive and continuous single crop exploitation.

I have the honour to be, Gentlemen,

Yours respectfully,

CLAUDE W. WARDLAW.

# PANAMA DISEASE OF BANANAS.

REPORT TO THE EMPIRE MARKETING BOARD ON A SCIENTIFIC VISIT TO THE BANANA GROWING COUNTRIES OF THE WEST INDIES, CENTRAL AND SOUTH AMERICA.

By Claude W. Wardlaw, Ph.D., D.Sc., F.R.S.E.

## INTRODUCTION.

PANAMA Disease of Bananas has already received considerable attention at the hands of scientists and at the present time published accounts concerning it have emanated from practically every banana growing country in the world. So widespread is the disease that it is unnecessary to enumerate these several countries at this point. So far as the investigations have gone the reports as to the nature of the disease are in substantial agreement, with some minor differences in detail.

It is now generally recognised that Panama Disease is a pathological problem of great complexity, occurring under a considerable variety of conditions. The several banana growing countries, however, are so vast and so varied in geology, topography, river action, soils, climate, etc., that investigations tend to suffer from the defect of localisation. Further, general scientific information regarding some of the larger countries is so scanty at the present time that a personal visit must be made in order that the special conditions prevailing there may be justly apprehended. Thus the ignorance and mis-statements which obtain with regard to the banana and Panama Disease may be taken as an indication of the broad scientific field which yet remains to be explored.

Under the Banana Research Scheme at the Imperial College of Tropical Agriculture, Trinidad, B.W.I., travelling facilities have been provided, and it has been possible to make scientific visits to a number of the more important banana growing countries. The present report will be concerned with an account of the author's travels in the West Indies and in Central and South America.

While many investigators have tackled the problem of Panama Disease even at the present time the work lacks completeness, and in fact has advanced little beyond the initial mycological stage. When it is stated that the disease is a wilt disease of great severity caused by the parasitic soil organism *Fusarium cubense* on the suckers and

roots, little has been omitted in assessing the extent of our present knowledge. The early investigators and their followers were so struck by the severity of the disease that they at once proceeded to launch an appeal for an immune banana to replace the Gros Michel in the trade and to apply drastic quarantine measures. Throughout the course of the several researches great stress has always been laid on the mycological evidence, and very little attention appears to have been given to exploring possible accessory conditions. This is readily understood, because the disease may apparently occur under such a variety of conditions that the investigator is led to conclude, hastily or otherwise, that the organism is such a powerful parasite that it will attack under all conditions—a statement not entirely justified when the manner in which the disease progresses is considered. All the evidence points to the fact that the mycological evidence must be read in conjunction with a sound knowledge of field and growth conditions and of the general physiology of the banana. It has already been suggested that banana information in current circulation suffers from the defects of incompleteness and localisation. Thus, for example, it is generally thought that the great abandonments of banana land in Central America were entirely due to the ravages of Panama Disease, and that all the land originally planted was of exceptionally high fertility. But such statements do not convey the whole truth. There were many reasons for abandonment, while even a little experience indicates that banana lands are very varied in type, fertility and staying power, to say nothing of important climatic differences. But information on these matters cannot be culled from rumour. The solution to the problem can only be justly sought by personal contact with the several local conditions. Regarding the nature of Panama Disease the pathologist on his travels has in mind two contrasting points of view. One is that the disease may be purely a matter of susceptibility as determined by the genetic constitution of the plant. The other is that the disease may be due to external conditions, soil, and climate, which adversely affect the health of the plant leaving it a prey to the parasitism of *Fusarium cubense*. It will be shown that as a rule, in our present state of knowledge, there is something to be said on both sides.

This report, based on seven months of travel in several of the important banana growing countries, gives the author's general impressions of banana disease problems, and is the basis for the experimental work which has now been commenced at the Imperial College of Tropical Agriculture, Trinidad, B.W.I. To the staff of the

College and to the facilities for work provided there, the writer is already deeply indebted. From the outset, Mr. G. Evans, M.A., C.I.E., Principal, has shown great interest in the research and has kindly assisted with all travel programmes. In thanking him the writer wishes also to associate Professor H. R. Briton-Jones, and Professor E. E. Cheesman. The former has already had experience with the problem of Panama Disease and has assisted by generous discussion at all times. To the latter, who has already made considerable progress with the uniquely difficult problems of banana cytology and genetics, the writer is indebted for much sound information regarding varieties and for constant assistance in the field. Such co-operation from members of the staff, and access to the collection of banana varieties on the College grounds available for study and experiment, are regarded by the writer as important factors in pursuing successfully any investigation into the physiology or pathology of the banana.

## BARBADOS.

At the present time the Windward Islands, together with Barbados and Trinidad, cannot be regarded as banana producing colonies, although all have bananas in cultivation for local use, and at one time or another have had a small export trade. Thus a banana industry was started in Barbados in 1902, the first shipment consisting of 18 bunches of the Canary banana (*Musa Cavendishii*), the second in 1903, of 6,669 bunches, jumping to 15,000 bunches in 1904, and 21,000 bunches in 1905. This small but prosperous business, however, did not continue, and Fawcett tells how a similar banana industry in Trinidad monopolised all the space available in the cold storage holds so that the Barbados fruit, of necessity stored in the ordinary holds, arrived at its destination in a rotted condition. The losses sustained under the attendant circumstances were so severe that shipments were discontinued and the banana land was planted up in sugar cane. An attempt was made in 1913 to restore the banana industry, but at the present time there is no export of bananas from Barbados ; in point of fact the reverse is the case and at certain seasons small quantities of bananas are imported from the neighbouring islands. If one might point a moral it would be that co-operation and not competition among these islands is the only key to success.

Apart from certain areas where the Dwarf Banana may be grown, Barbados is not a banana country. The soil is too porous, the rainfall

is low, and the island is constantly swept by winds. There are no banana estates to be visited in Barbados at the present time. I visited two small holdings where disease was reported, but these proved to be physiological troubles due to insufficient attention and the need for soil improvement. All the bananas with the exception of those growing in favourably sheltered habitats appear to suffer from drought in the dry season, the leaves being wilted and folded, papery, and whipped to tatters. Chlorotic plants were observed growing in the screes of calcareous cliffs. In the North East district where the soils are very friable and of a red and brown colour, one can still see the remains of the old banana walks. No Panama Disease has been reported from Barbados.

## ST. LUCIA.

During my visit to St. Lucia in June (1928) I was able, with the co-operation of Mr. E. A. Walters, Superintendent of Agriculture, to examine all aspects of the Banana industry there. This visit was especially interesting because it indicated clearly the great need for scientific knowledge before launching any new agricultural project. Like Trinidad and Barbados, St. Lucia has now no important banana industry, but as recently as 1922 there was a somewhat ill-conceived venture in that direction. As the whole history of this attempt to establish a banana trade is known, I suggested to Mr. Walters that he should write an account of it from the commercial and scientific point of view. This is now available in the form of articles submitted to *Tropical Agriculture*.* From the standpoint of an investigator the points are as follows. Towards the end of 1922 a banana company took over an area of Crown Land Forest in the Ravine Poisson, cleared the land sufficiently to allow of planting, and felled the virgin forest, more or less following the method commonly used in Central America. The land was chosen and the operations commenced without seeking the advice or assistance of the local agricultural authorities. The first plantings, to establish a nursery, were made from suckers of the Gros Michel collected promiscuously throughout the island, and there can be little doubt that much defective and diseased material was introduced into the nurseries at the very outset. The first cases of Panama Disease were observed towards the beginning of 1924. By this time the Agricultural Authorities had been called in to give advice on Weevil and Borer

* *See* Appendix.

pests and other difficulties, and certain preventative measures based on the Jamaican regulations were applied. Planting went on, Panama Disease was observed in several new localities, new troubles arose and the Agricultural Department did good work in several directions, notably in the selection and preparation of planting material, whereby a considerable reduction in the amount of disease was effected. From an original area of 200 acres in the Ravine Poisson cultivation was extended to 1,000 acres, so as to include the Vanard Estate. But the industry was not destined to be successful. Overhead costs were heavy, porterage was difficult and expensive, and after four

*Fig. 1.*—Banana land in St. Lucia, showing the steep exposed hillsides, into windbreaks of the original forest trees. In the foreground is a typical abandoned area in which the remaining bananas are gradually being crowded out by secondary vegetation.

shipments the industry collapsed, not on account of Panama Disease, but on financial grounds. By 1925 the whole attempt had completely failed and the banana lands were allowed to go back into secondary bush. My investigations in the Ravine Poisson and Vanard were, therefore, made on derelict land covered with secondary bush. While these banana lands are not of the first class judged by Central American standards it is important to note that Panama Disease,

though it had caused great havoc in the first 200 acres planted, was not the cause of failure. At the time of abandonment there were still big areas growing good fruit, with localised bad patches of Panama Disease. From the scientific aspect these areas present many points of interest. Judged by the Central American concept of banana land for large scale production, the soils of St. Lucia are unsuitable. The plantations were situated on steep hillsides, road-making was very expensive as it necessitated deep cuttings and bringing out the fruit undamaged was difficult. Further the soil is not of the first order in its natural state being for the most part a rather sticky

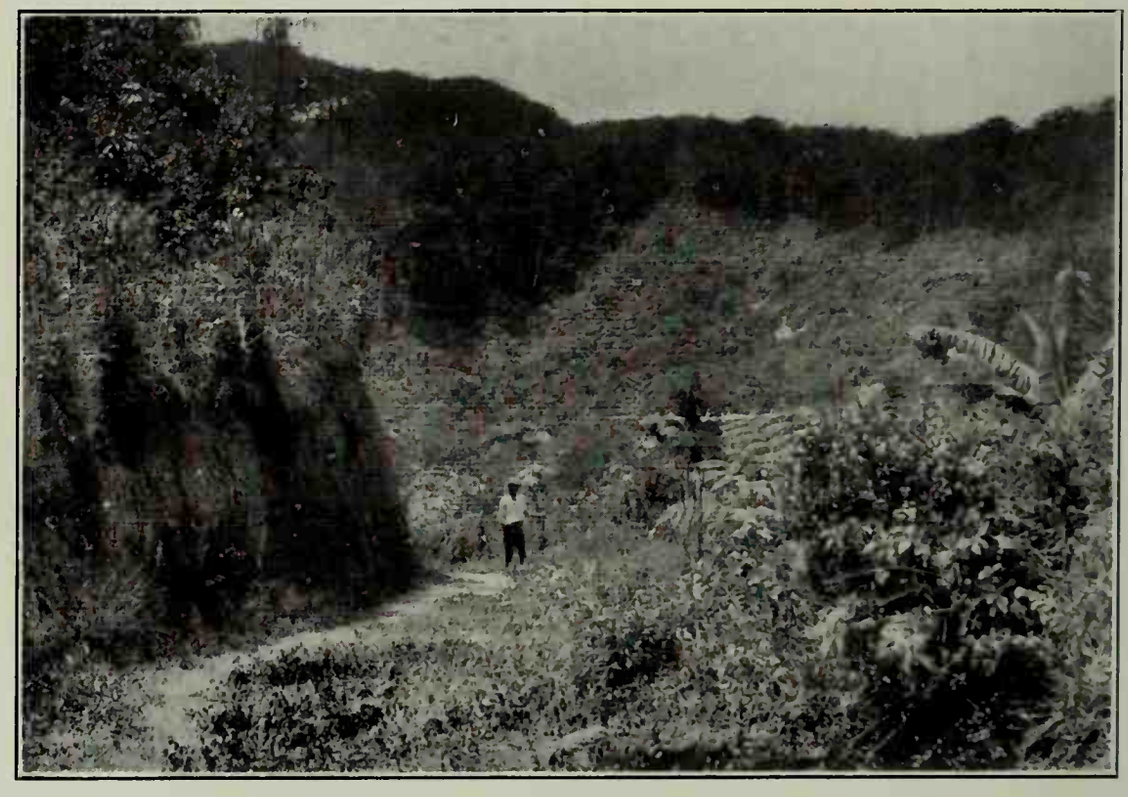


*Fig. 2.*—An example of the deep cutting required to secure a roadway into the Ravine Poisson, St. Lucia. This type of excavation extends from the bottom to the top of the ravine.

loamy clay of red or yellow colour, with defective aeration and drainage. Such soil puddles readily, has all the defects of impervious clay, and is not readily modified by the decaying surface mould. In short this type of soil requires to be worked before planting, if a good staying fertility is to be obtained. Near the top of the ridges where one finds the stiff clays which have resisted denudation plants show drought symptoms in dry weather, while in the hollows below

*Fig. 3.*—A general view of an abandoned hillside area, showing Gros Michel bananas in competition with the secondary vegetation.

where detritus has collected a more uniform undisturbed growth is the rule. The Gros Michel banana does not take kindly to soil of this kind, and in many instances I found the plants growing like soil epiphytes rooted in the accumulation of their own mould. Where the roots had penetrated into the clay they were obviously water-soaked and diseased. In such habitats there is clearly an important problem of root decay in addition to that caused by the Panama Disease organism. Land of this type, though of high potential fertility will not give good results unless it receives suitable agricultural treatment. In Central America where there is no cultivation (in the sense of thorough tillage) the good banana lands consist of deep alluvium, and on such soil, with the help of rough bushing, the Gros Michel is able to thrive. Again, in Jamaica, land corresponding to that of St. Lucia has supported bananas for many years, but there tillage is the rule. In St. Lucia, on the other hand, no tillage (other than digging a small hole to plant the sucker or " bit ") was given and there is little doubt that such treatment would not be conducive to long-lived highly productive plantations on these difficult hillside soils. There is an idea prevailing in many quarters that all virgin land is necessarily of unbounded fertility, but a little experience shows that the term " virgin soil " may include a wide range from a rich deep alluvium to surface material which is more in the nature of a juvenile geological stratum than soil. Thus in the question of tropical soils we have a hundred unexplored problems. The experience in St. Lucia clearly indicates that under the conditions described above the soil quickly undergoes a marked deterioration when planted in bananas. The secondary bush which encroached on the abandoned areas was of a poor type and the dominance of certain ferns may be taken as an indication of the biological conditions. In order to conserve the natural wealth of such land, therefore, some kind of detailed agricultural treatment is essential.

With regard to the economic value of the original banana lands, Walters offers the suggestion that the best areas would serve admirably for coffee. Such suggestions are welcome because one of the major difficulties under such conditions is to find a suitable alternative crop. Numerous examples of Panama Disease were observed, but in the area where such plants occurred there were still many healthy plants carrying fair bunches of fruit. Good plants were frequently observed in close proximity to diseased ones, and in view of the fact that the organism has had at least two years to spread from infected stools

to the neighbouring ones it makes one doubt some of the current theories and statements concerning the nature of the parasitism. Considering that the organism can grow through the soil, coupled with its alleged virulence under all conditions, theoretically there should be practically no bananas left standing. But this was not so. In St. Lucia the question of Panama Disease is rendered more complex by the growth of the Gros Michel under conditions not entirely suitable. To what extent these two aspects are related remains to be demonstrated by critical experiment.

*Note.*—According to Walters, the frequency of Panama Disease was as follows :— S.W. area of the colony, 0·7 per cent. ; N.E. area, 2·5 per cent. ; lands of Banana Company from 0·5 per cent. to 20 per cent.

## COSTA RICA.

Commercial banana production began in Costa Rica about 1880, when only 360 bunches of bananas were exported, but after the railway was opened production increased rapidly till it reached about 10 million bunches annually from 1908–11 :—

| | |
|---|---|
| 1882 .. .. .. .. .. | 3,500 |
| 1892 .. .. .. .. .. | 1,178,812 |
| 1902 .. .. .. .. .. | 4,174,199 |
| 1908 .. .. .. .. .. | 10,060,009 |
| 1909 .. .. .. .. .. | 9,365,690 |
| 1910 .. .. .. .. .. | 9,097,285 |
| 1911 .. .. .. .. .. | 9,309,586 |

Since then the abandonment of land for banana cultivation has led to a decrease in output, so that Costa Rica took fourth place in the export of bananas in the Caribbean with a total of 7,660,000 bunches in 1926.

The interior of Costa Rica is highly mountainous, the lofty volcanic ranges following the general trend of the continent from N.W. to S.E. On the Atlantic and Pacific sides of this broken central table-land are narrow coastal plains some 30 miles in width. Denudation in the upland regions is rapid, and swift rivers, constantly carrying sediment, flow down to the plains and deposit rich beds of alluvium. The river courses along the plain are flat and meandering, with the result that these alluvial lands are constantly in the process of formation.

The climate on the Atlantic side is very humid. The high rainfall is distributed over the whole year, with a rather drier period from January to April. As a result of the high precipitation and rich

alluvial soil, the Caribbean coastal plain and hillsides are covered with dense tropical rain forest—giant trees, with a heavy undergrowth of lianes, and Palm jungles. It is this land which has been pressed into the service of large scale banana production.

The writer had the opportunity (by courtesy of the United Fruit Company) of visiting the banana lands of Costa Rica on two occasions, in July and September, and was able to see most aspects of the industry in its present state. Banana cultivation in Central America by no means infers detailed agricultural operations such as tillage,

*Fig. 4.*—An alluvial area in Costa Rica, covered in virgin rain-forest vegetation. This indicates the nature of the country that has been opened up for large scale banana cultivation.

liming, upkeep of plant food, etc. It would be more accurately described as the exploitation of the native fertility of virgin soil with the minimum amount of detailed treatment. The method of establishing a plantation is briefly as follows. An area is surveyed and the underbush of the virgin forest is cutlassed sufficiently to allow the laying out of the rows, the position of each stool being marked by a stake: suckers or "bits" are then planted in holes 15 inches in diameter and 15 inches deep. The tall forest trees are then felled

and after some time the young banana plants begin to appear through the mass of trunks, branches and twigs. As both the growth of the plant and the decay of the forest debris take place quickly, in a very short time, with periodic cutlassing of the secondary bush, an orderly plantation is established.

During my first visit in July I was able to see examples of the best and of the worst plantations, and this afforded a valuable sense of contrast. For the most part the plantations are situated in flat country along rivers, lagoons, and railways, on rich alluvial soils deposited by

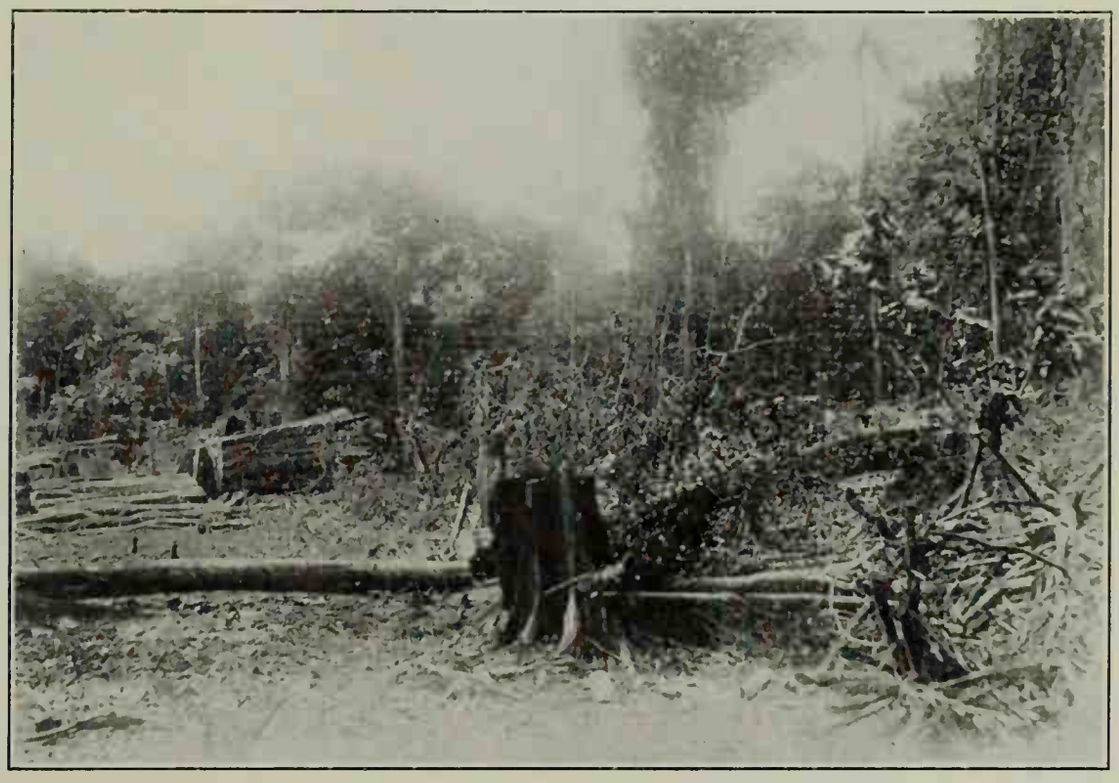


*Fig. 5.*—Felled forest land in Costa Rica being opened up for banana cultivation.

the meandering rivers. In some districts the latter may overflow two or three times a year. Monte Verde, the first farm visited, is situated some 30 miles out of Port Limon, on the main line to San José ; it consists of an extensive area of flat country originally clothed in tall forests of giant trees. I was informed that the farm extends over 2,000 acres, has about 900 labourers, a tram-line system, loading sidings, many mules, and hundreds of pontoon bridges. This piece of country is very flat, lying perhaps 100–150 feet above sea level. Drainage is into an adjacent river whose course is marked by many

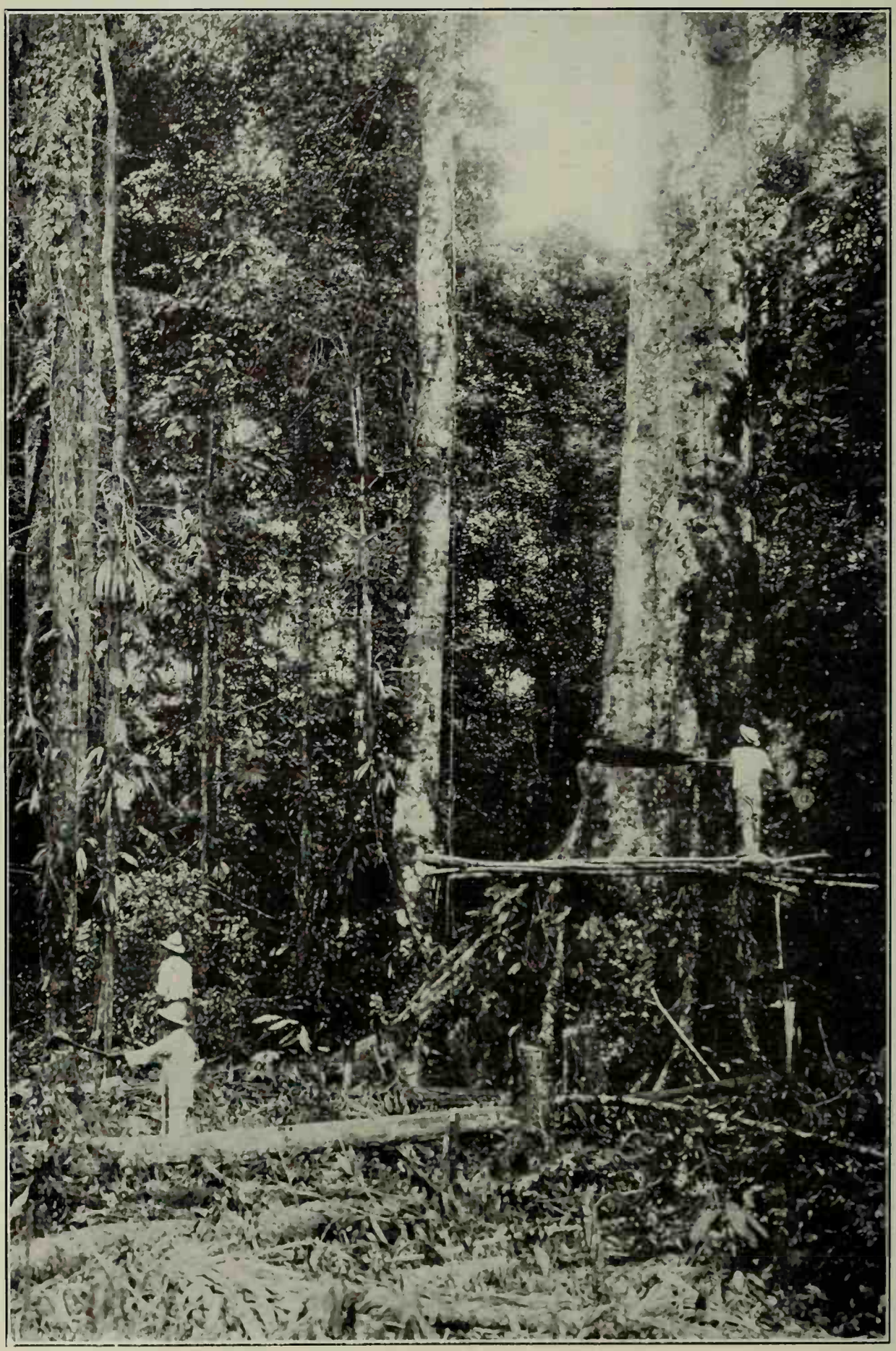


*Fig. 6.*—Felling operations in a Costa Rican forest in preparation for banana cultivation.

*Fig. 7.*—A banana plantation at an early stage. The young plants are pushing up through a tangled mass of trunks, branches, and twigs. Costa Rica.

*Fig. 8.*—Appearance of new plantation in the apparently disorderly early stage. The land is covered with forest debris from giant trees (*see* right hand side) through which the young plants, set out in rows, are pushing up.

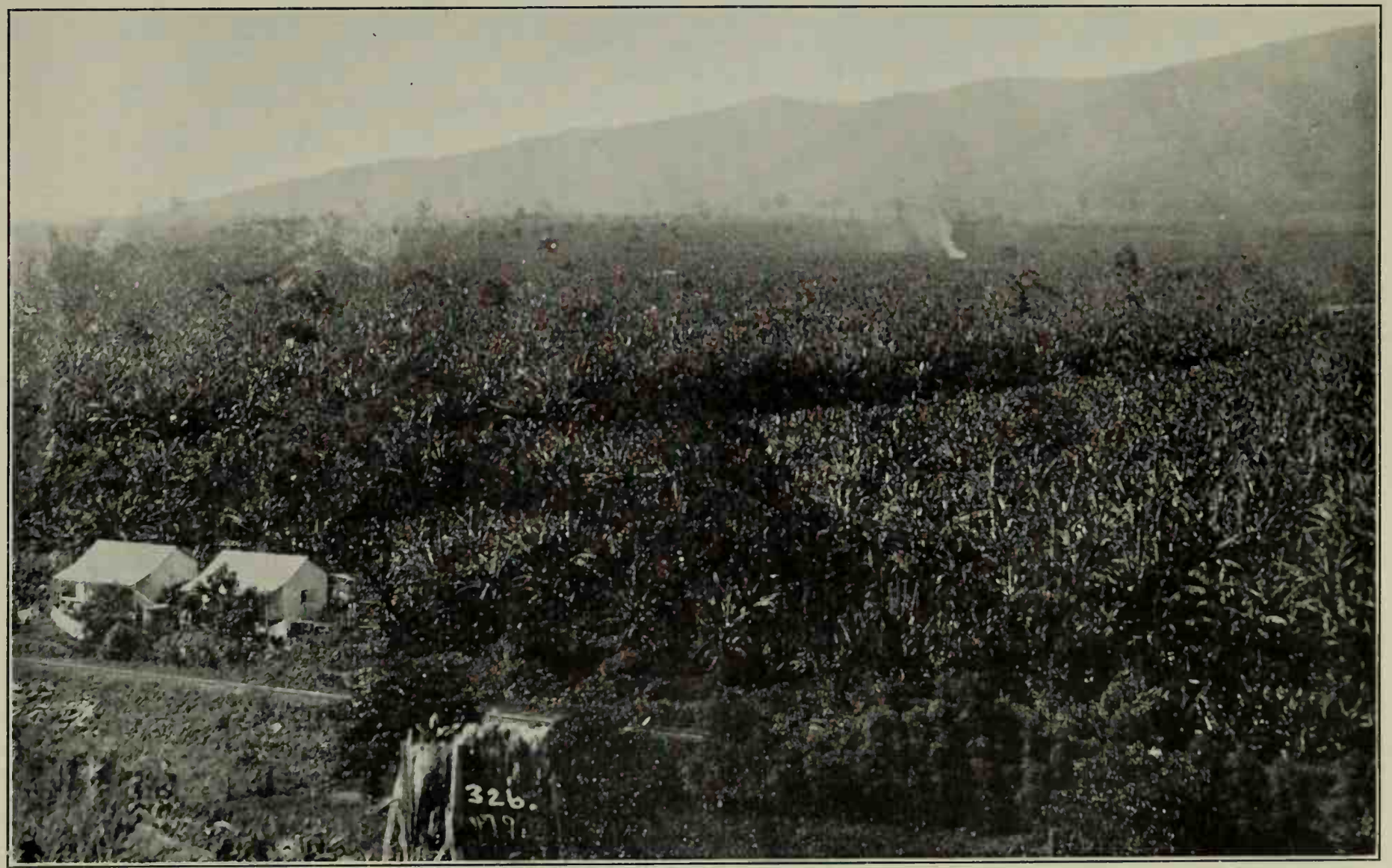



*Fig. 9.*—A Costa Rican alluvial plain, originally covered in dense forest, transformed into productive banana plantations. This illustration gives some idea of the extensiveness of some of the valleys under bananas.

loops, some of which are eventually shut off as lagoons. Although the land is superficially uniform—the result of successive depositions of river alluvium—yet marked differences occur in the soil, the natural flora, and the banana plantations from area to area. When such land is opened up for banana cultivation this soil variability is reflected in the growth and longevity of the banana plantations. My first visit was to a very good plantation, which had been producing consistently for 20 years. It was a remarkable sight. The plantation as a whole was marked by great uniformity of growth, by tall robust plants of high productivity, by the miniature undergrowth which scarcely required cutlassing, and by the absence of Panama Disease. Examination of the soil showed it to be a free, well-drained, moisture-holding dark sandy loam. In other words, in its natural state it was practically an ideal banana soil. I had a section dug through a stool to a depth of four feet. The excellent soil observed on the surface continued downwards with a slight increase in the quantity of finer particles, and it was noticeable that the majority of the roots penetrated vertically downwards, rather than horizontally ; they were free from disease, white and turgid, with a plentiful growth of unblemished lateral rootlets.

The presence of easily observed root-hairs may be taken as an indication of the soil texture. Uprooting by wind was at its minimum in this plantation. Lastly, it should be mentioned that there was an even transition (from the surface vegetable mould from a species of *Tradescantia*) down into the lower depths of the soil. These several points, together with a knowledge of the age of the plantation may all be taken as indications of exceptional fertility and suitability to the Gros Michel. In fact, it gave one a definite concept of a high class Gros Michel soil which proved very useful in subsequent comparisons. All the soils of this area, however, were not of the same high order. A second soil examined did not support the same strong even growth ; it was of lighter colour, was less sandy and open in texture, and tended rather to stiffness and compactness. Other similar soils were examined. These were silty loams of brownish colour, so compact as to make root penetration difficult, and somewhat mottled and streaky, indicating deficient local drainage and lack of aeration. Alluvial soils of this kind would doubtless respond to even a little treatment, while mechanical stirring, if only to a minor extent would greatly improve root formation and health by allowing greater freedom and aeration. But this they do not receive in the present

state of agricultural development, and the banana plant has perforce to grow as well as it can from the 15-inch excavation in which it is planted. The contrast between these latter soils and the first one described was very marked indeed. Other areas of poorer soil showed smaller banana plants, uneven growth in the plantation as a whole, gaps here and there, and a greater amount of Panama Disease. Where the growth of the banana is poor and uneven the secondary bush naturally is much more active in growth, and requires to be cutlassed more frequently. Thus, quite apart from the ravages of Panama

*Fig. 10.*—The River Reventazon, Costa Rica. This is a typical banana river. It brings down rich silt from the hills, and deposits it as it meanders across the plain. This photograph illustrates the nature of land resulting from a succession of silt depositions. The river banks are built up as the result of a succession of floods.

Disease certain plantations fail to give the necessary margin of profit because poor production of fruit goes hand-in-hand with higher cost of upkeep. Very good soils, or soil replenished every year by the deposition of good alluvium from the rivers, appear to be rich enough to stand continuous cultivation. Other soils of the second or third class of fertility may last from 7 to 10 years. In the deterioration of tropical soils which takes place under these methods of exploitation

we have a problem of first-rate importance. Its solution is to be sought in the conservation of fertility by detailed agricultural treatment or by a suitable rotation of some kind.

With regard to the occurrence of Panama Disease it was observed practically everywhere, but it was most accentuated where growth as

*Fig. 11.*—A typical lagoon (a river backwater) in new banana land, Costa Rica. The presence of the high-water lagoons often makes drainage operations difficult. The richness of the rain-forest vegetation is also indicated.

a whole was poor. On the other hand, areas were observed where weakly plants prevailed, but where there was little Panama Disease. With regard to the spread of the disease, current theories are not

borne out in Costa Rica, since good plantations of 20 years standing are still flourishing free from disease, but with every chance of infection from surrounding plantations which have suffered from it.

During my second visit to Costa Rica in September, I made a special point of examining the abandoned banana lands. This was part of a visit to the old banana lands of Panama undertaken in order to acquire personal observations on those areas where Panama Disease first became prominent. If one were guided by rumour and hearsay

*Fig. 12.*—Poor banana land in Costa Rica, where the stunted bananas will soon be smothered by the vigorous growth of a coarse grass.

alone, the inevitable conclusion would be that Panama Disease was responsible for all the abandonments in Central America. The truth of this assertion will be discussed in due course.

My first expedition was to the Siquirres district where some of the lands have been abandoned for the last two to five years after about 15 years of banana production. Here many cases of Panama Disease were observed. As one commonly finds there was considerable variability in the external symptoms, but internal symptoms were of the usual description. One area abandoned for four years was so

grown up in secondary bush that it was necessary to cut a way through. When the soil was examined it was found to be a sandy loam, very mottled and suffering from insufficient drainage. The trouble here, as in many other farms in Costa Rica, lay in the natural compactness of the alluvium, and in the lack of upkeep of the main and lateral drains. These defects generally go with wetness, troublesome grasses, and strong bush. On such soil the root system of the Gros Michel was found to be superficial and horizontal, while roots penetrating the mottled levels were blackened and diseased. Another area had been completely abandoned for the last five years, so that

*Fig. 13.*—Typical abandoned bananas in Costa Rica, showing the heavy overgrowth of secondary vegetation.

the standing vegetation consisted of the remaining clumps of bananas, secondary bush and grass. The cause of abandonment was lack of production due to poor growth, high water-table, grass and bush, Panama Disease, and in general, bad upkeep. Such an area provides interesting material for the study of the Gros Michel, when it is growing under unfavourable conditions in open competition with the natural weed-flora. Grass smothering is common where conditions make for a slow and lagging growth of the young banana plant. Here I made some observations on the behaviour of Panama Disease. A

remaining clump of fully-grown bananas had a Panama Disease case in the centre, but the surrounding stools were not affected, although the disease had had at least five years to run its course. How did the central stool become affected, and why did the disease not spread to the adjacent stools ? This is but one of the many puzzles with which the investigator is faced in the field.

The following day a visit was paid to some of the plantations near the banks of the River Reventazon. This river brings down quantities of silt from a calcareous region and I was informed that, on the whole, the banana land on its banks was not so subject to Panama Disease. Most of the other rivers deposit an acid silt and disease is more abundant. Again the River Barbilla (a tributary of the Matina) flows through calcareous rocks, while the other tributaries do not. The Barbilla land is said to have but little disease, whereas the other river banks are badly affected. The inference is that soil acidity is a factor which favours the attack of *Fusarium cubense*, while neutrality or alkalinity controls it. In some of the farms visited it was noticeable that patches of disease occurred in open sandy soil, and not to the same extent on good alluvial soil near by. Reports of the occurrence of disease on sandy soils come from many quarters accompanied by the suggestions that acidity, leaching, or rapid propagation of the fungus are possible explanations. This seems a point amenable to experimental investigation.

The farms of St. Louis and Parismino, extensive areas of good dark alluvium, originally under bananas and later abandoned, are now under cacao or in pasture. As far as can be determined by inspection in the field the soil is remarkably good, yet one is informed that this and similar areas were very quickly wiped out with disease from 1912–14. Such soil even though acid should be productive. From observation of this kind one is led to conclude, either that the organism of Panama Disease is so virulent that it will attack the Gros Michel grown under the best of conditions, or that there was a widespread planting of bad and diseased material. For the latter point of view there appears to be a certain amount of justification. It will certainly be admitted that the rapid expansion of the industry coincided more or less with the wide occurrence of the disease. Further, at such times, to acquire sufficient planting material is always a difficulty and much defective stock is pressed into service. As diseased suckers will almost certainly give diseased plants there may thus be an

important outbreak on the best of land. But, unfortunately, on these points we have no exact information, and in Costa Rica it is now impossible to obtain records of this period. If, however, the material planted on these soils was good, then one is left with the impression that *Fusarium cubense* is an exceedingly active parasite and that the genetic constitution of the Gros Michel is such as to make it susceptible under any conditions. A third possibility is that there are adverse soil factors which will only be revealed by careful analysis and experiment.

The next excursion was to the abandoned lands in the Banana River and Estrella Valley districts. Here many of the original Gros Michel plantations have been replaced by cacao, Red Banana and pasture. The land consists of flat stretches of river alluvium interrupted by clay mounds and spurs running down from the neighbouring hillsides. As a result the soil is very variable from area to area, consisting of various river deposits, clay washings from the hillsides and the original weathered soil *in situ*. The reasons for abandonment in this district are not always known, but Panama Disease and various other adverse factors are indicated. It should be mentioned, however, that some of the abandoned lands have been successfully brought back into banana cultivation. In many instances the Gros Michel had been replaced by the Red Banana, and the latter was frequently observed with Panama Disease. This raises the very interesting question of immunity, susceptibility, and the influence of external factors, because the Red Banana, normally highly resistant, may under certain circumstances actually succumb to Panama Disease. In certain areas a kind of leaf scorch was observed in the Red Banana which suggested a functional trouble. There are many ailments which fall into this category. One, locally known as Talia Disease (named after the farm where it occurred), results in the formation of a fruit canker, consequent on a kind of physiological breakdown. No organism was isolated by those who investigated the problem and it was too local in occurrence to merit further attention. In the districts under discussion Panama Disease was very conspicuous but not more so than bad patches due to water-soak and poor upkeep. In some of the properties drainage was noticeably poor, and drains had either never been present, or had long been filled in. In such places it was clear that Panama Disease was by no means the limiting factor. At no point was there a noticeable spread of the disease progressively away from the original infected locality.

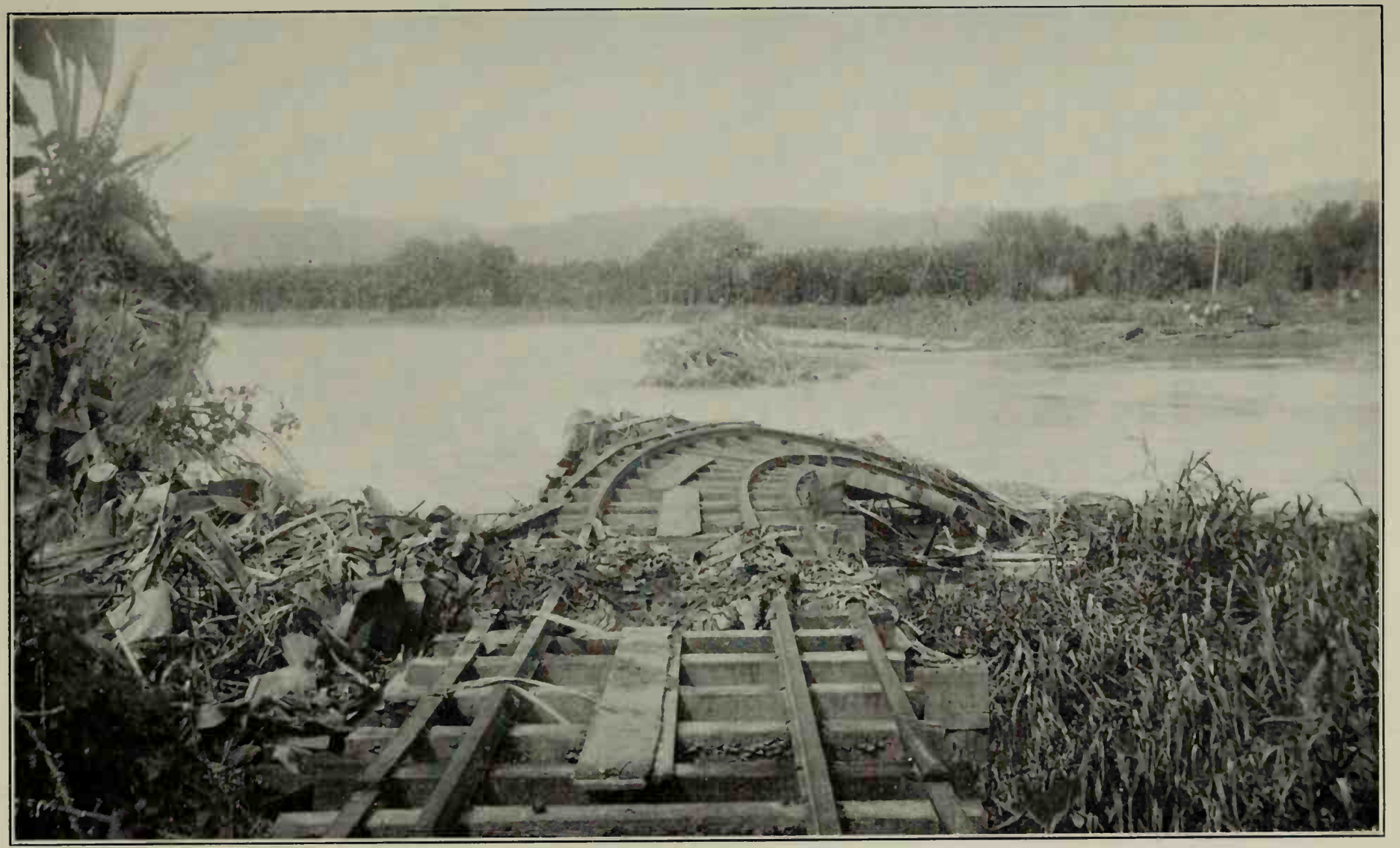


*Fig. 14.*—Flood conditions in the Estrella Valley, Costa Rica. The rivers rise rapidly and cause great damage to plantations, railway bridges and houses.

*Fig. 15.*—Demolished banana plantation after a flood, Estrella Valley, Costa Rica.

In contrast to these poor areas some very good bananas, of 30 feet or more in height, were seen in a section where a special type of " cleaning " was in use. This consisted in shovelling the ground clear of all vegetation so that the weeds and detritus formed a heap between the rows. The growth was enormous and the output of fruit consistently high. The soil was a very rich deep alluvium close to the river bank, and although superficial drainage was good, the soil was considerably mottled close to the surface. One is led to speculate on the enormous fertility of such land if it were properly aerated even by the minimum amount of tillage. In spite of the very strong growth, close examination revealed the fact that a very considerable amount of Panama Disease was present, and the whole position suggested an interesting struggle between the vigorous growth conferred on the plant by the richness of the soil and the wilting action due to the fungal attack.

Among the many problems and difficulties to be met in these areas are the disastrous floods which cause very considerable damage to crops, bridges and houses.

With regard to the chemical composition of the banana soils of Costa Rica as a whole, Prescott remarks that they are fairly high in iron and aluminium, low in lime and magnesia and in a few instances low also in potash and nitrogen. While in Port Limon I had the good fortune to meet Dr. Reinking, Pathologist to the United Fruit Company. We had several conversations on Panama Disease and banana problems in general, and found ourselves in substantial agreement on most points concerning the present state of banana research.

The results of my visit to Costa Rica may be summarised as follows :—

(1) The banana properties in Costa Rica are so extensive that months would be required even for a general reconnaissance, while a detailed survey of the very diverse soil conditions, climatic and other factors, could only be achieved by a prolonged stay in the country.

(2) It is now very difficult to obtain exact information regarding the history and development of the various banana properties, the reasons for abandonment, the number of years under crop, and so on, as records either were never kept or have been lost.

(3) It is said that there is now practically no farm in Costa Rica free from Panama Disease.

(4) There is much very good land now in cacao or pasture which was originally planted with Gros Michel. This is alleged to have been quickly wiped out by Panama Disease. Whether this was due to the very vigorous parasitism of *Fusarium cubense*, the use of bad material, or some unrevealed soil factor, is not definitely known. It should be mentioned, however, that land planted once and affected with disease was seldom replanted, so that, as elsewhere, there is a lack of sound experimental evidence.

(5) Examples were seen where rather inferior land replanted was absolutely riddled with Panama Disease.

(6) The new land which is being opened up in Costa Rica at the present time is not regarded by those in charge as being of the first class. The main difficulty of the larger fruit companies at the present time is production. About 75 per cent. of the banana properties are privately owned.

(7) In Costa Rica, while undoubtedly Panama Disease is important at the present time, it is not the chief or only cause of abandonment, and probably the same is true of the past. Other important causes are low output due to poor land, high cost of upkeep, water-soak and drainage, grass, bush and bad upkeep. As a rule, however, Panama Disease is made the scapegoat.

(8) In general, agriculture in Costa Rica is still in the preliminary state of broad exploitation and there is little to indicate that the day of more detailed husbandry is at hand.

## GUATEMALA.

The eastern banana lands of Guatemala are situated in the humid tropical region of the lower Motagua Valley on the Caribbean coastal plain, with Puerto Barrios as the point of export. The alluvial and hillside soils on which bananas are grown are derived from the complex mountainous hinterland of igneus and volcanic rocks. The large areas of alluvial soil on either bank of the Motagua River have been laid down by a succession of floods, and even when low the river carries along considerable quantities of sediment. This alluvium is very high in silt and clay as a rule, and as a whole the soils are deficient in lime. The rainfall is abundant during a large part of the year, and in its virgin state the banana land was clothed in high tropical rain forest. The export of bananas from Guatemala in 1926 was 5,900,000 bunches.

The banana area* easily accessible by railway consists of flat alluvial land traversed by slow silt carrying rivers. Already there is a considerable acreage under bananas, part of which has been abandoned, but much more extensive areas have yet to be opened up. Some of the alluvial soils of the Motagua River are remarkable. One soil examined consisted of a rich dark alluvium, of such texture as to make for ideal water-relations, and extending downwards uniformly for at least seven feet. Zones of such soil occur extensively on either side of the river ; the latter at this point is fairly broad, slow moving, muddy with its constant burden of silt, and liable to overflow, when large quantities of good alluvium are deposited.

*Fig. 16.*—The Motagua River, Guatemala. This illustrates the large alluvial flats laid down by river floods—banana land of the future.

The bananas in this section showed strong uniform growth, were free from disease and have proved highly productive over many years.

Drainage operations have been carried out on a very elaborate scale, the ideal being an adequate system of four-foot drains. This brings the water-table down to at least three feet, thereby providing the banana with ideal conditions for sound root development. The

* Visited by courtesy of the United Fruit Company.

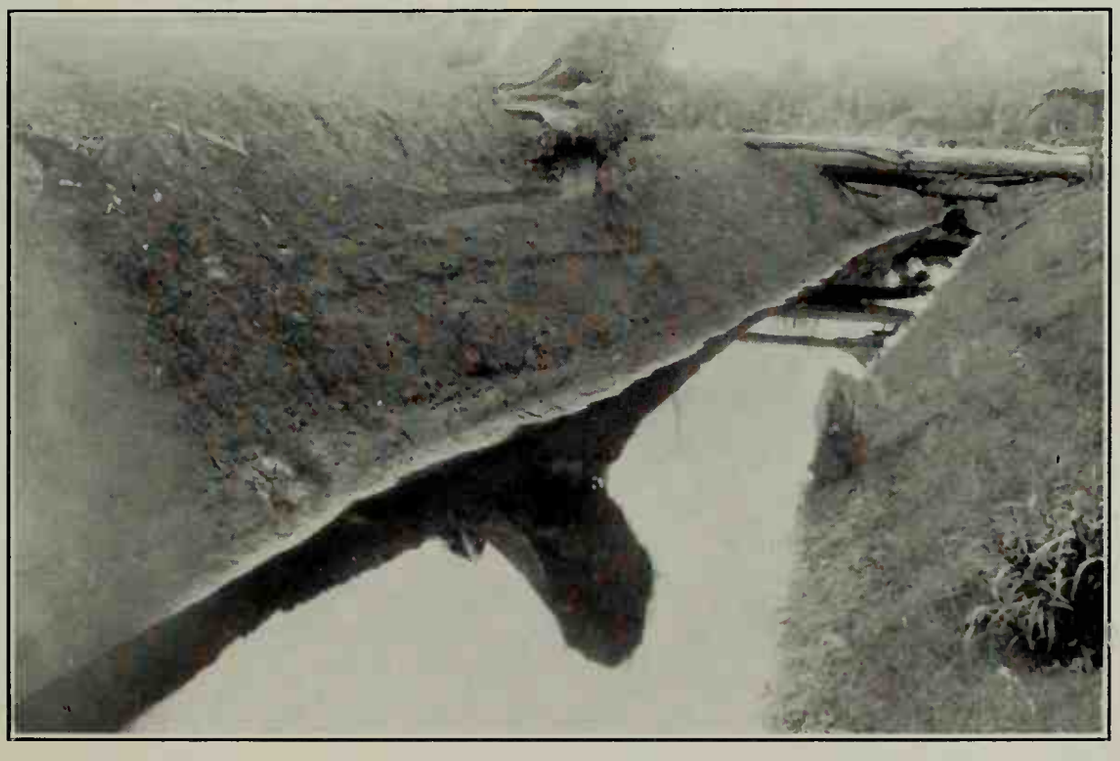
deep main drains permit of detailed examination of the alluvial deposits. The uniformity of the deep loam was surprising, as at all depths the texture permitted of good local drainage. At one point where the contour allowed of bog formation a deep extensive waterway had been constructed to keep the water at a suitable level. Extensive operations such as these, based purely on economic results, are indicative of the high quality and productivity of the land.

My next visit was to an area where felling had just been completed, and where drainage operations were in progress. The felled logs of great size were quickly decaying under the influence of saprophytic

*Fig. 17.*—A typical area of poor plants suffering from water-soak, caused by high water-table and periodic flooding ; Guatemala.

fungi thereby forming a rich layer of mould on the soil surface. In the absence of functioning drains the soil still bore the marks of long water-logging. The latter is one of the greatest difficulties in this area, and is the chief cause of blanks and poor plantations. I was informed that another cause of blanks in new areas was the use of bad planting material.

Adjacent to the good land just described there were areas which had never been brought into cultivation either because of their boggy



*Figs. 18 and 19.*—Two examples of the very efficient drainage systems in the banana plantations of Guatemala. These main drains, together with the lateral ones, quickly remove excess water from the uniform deep alluvium.

nature, and drainage difficulties, or because the soil was a stiff silty clay with a tendency to sourness. Originally such areas had been covered with high forest and Cohune Palm (*Attalea cohune*).

At my request a special visit was made to a section where disease and cultivation were at their worst. In some localised spots there were poor stunted patches attributed to soil exhaustion, but in the main, the greatest trouble, and indeed the only cause of defective growth in some good alluvial areas, was water—largely on account of river flooding. Thus in one stand of good plants the river had overflowed to a depth of 3 feet, and had remained so for 10 days at one time and 11 days a little later. The effect of such flooding was :—

(1) to deposit very considerable quantities of high grade silt—agricultural land of the future.

(2) to destroy more or less completely bananas in the inundated areas. The plants had a stunted yellowish green appearance.

(3) to impart to plantations not so badly affected yellow foliage, spindly trunks, and poor growth.

An interesting contrast between flooded and non-flooded land was afforded at one point where the railway embankment served as a barrier. The soil was of the same texture on both sides, but the plantation on the river side was devastated as described above, while that on the protected side supported well grown vigorous plants.

At various points the rich alluvial flats are interrupted by spurs from the neighbouring hilly country. These consist of a red clay, sometimes stiff, cheesy, compact and mottled with yellow and sometimes reduced by weathering to a lateritic condition. In contrast to the high-grade alluvium this red soil is notably poor for banana cultivation, and as experience showed that it only produced for a very limited number of years and was subject to Panama and other diseases, it is now avoided in Guatemala. This type of formation occurs all over Central America, and I have observed that if planted in bananas it consistently goes out after a very few years. Geologically it is associated with the rolling hilly formation, and represents a soil of a stiff adhesive nature which does not readily succumb to denudation. The acidity attributed to these soils is in contrast to the alluvium deposited by the Motagua after its passage through limestone country.

All the alluvial flats in Guatemala, however, have not proved equally successful as banana propositions. In some sections there are large areas which have proved unproductive, and have been

abandoned on account of Panama Disease, soil sourness, and difficult stiff clay texture. At the present time these areas support secondary bush of an inferior kind. A soil inspection revealed a highly mottled clay soil on the surface, to a depth of 3 to 6 inches ; underlying this was a sticky blue clay which undoubtedly exercises a toxic effect on the roots of the Gros Michel. Such areas were mostly adjacent to the hills. Further, on examination of the neighbouring streams and creeks it was found that these were running clear on a stony or gravelly bottom. The obvious inference is that this area has been subjected to considerable denudation. The useful alluvial materials have all been washed off and transported down stream leaving behind the more resistant clays of the hill formation.

Arapahoe Farm, some 53 miles from Puerto Barrios by rail, lies close to the Motagua and is of especial interest. Originally this land was abandoned on account of inundation caused by the overflow of the Motagua. The soil was a very good sandy alluvial silt, however, had originally supported very big timber, and seemed eminently suitable for bananas. At very considerable cost a levee to exclude the overflow of the river was built, and as a result a very large area of rich land was made available for bananas. At the present time this land is in a very high state of production with very little Panama Disease.

With regard to the occurrence and spread of Panama Disease the following points were noted :—

(1) On the good open alluvial soils there are few cases of Panama Disease. Some of these have been under observation for a number of years and no spread of the disease has taken place.

(2) Resistance to Panama Disease has been observed on both alluvial deposits and clay soils.

(3) The abandoned areas are mostly on red clay, hilly land, brown mottled clay, and in general on soils that are not of the first class.

(4) At the present time areas of poor bananas are mostly due to flooding and high water-table rather than to Panama Disease, and banana losses are often due to the choice of unsuitable land in the first instance.

(5) The most severe attacks of Panama Disease took place on the red clay lands. The durability of such soil is limited to some 5–10 years. On this subject Prescott mentions that of seven

samples in which marked silt deposition takes place, six have had an excellent cultivation history ; while of twenty-three samples in which there was no silt deposition only thirteen have a good history. Good cultivation history has been found to coincide with good soil texture.

(6) Abandoned areas have been brought back by suitable attention.

(7) Guatemala has still many areas of good land suitable for banana production.

## BRITISH HONDURAS.

British Honduras, the only British colony in Central America, lies in the South-Eastern corner of the Yucatan peninsula, between the latitudes of 15° 53′ and 18° 30′ North. At the present time the colony supports but a scanty population and much exploration must yet be done before its possibilities can be accurately assessed. With the exception of forestry, there is a great dearth of other scientific knowledge regarding the colony ; this is reflected in the fact that an agricultural officer has been appointed for the first time during the present year.

The climate is sub-tropical and humid, the country is intersected by many rivers, and the vegetation is rich and varied.

The output of bananas from British Honduras is small, the total for 1926 being only 161,281 bunches. Hitherto the industry, located mainly in Stann Creek Valley, Riversdale and Monkey River, had produced about half a million bunches per annum, but this has declined considerably on account of Panama Disease and other difficulties. The major operations were commenced in Stann Creek Valley about 1907–1908, when broad scale plantations of Gros Michel were established as in Costa Rica. At the same time a Government railway was built to carry the fruit down for export. Unfortunately the venture did not meet with the success that was expected and attention is now being given to the extension of other industries to replace the banana.

Stann Creek thus presents an interesting field for the pathologist, and during my brief visit I was able to make a number of observations which throw light on the banana situation there. The several excursions were made in company with Mr. J. N. Oliphant, Conservator of Forests, and members of his staff.

After leaving the pier at the marine terminus of the railway, one passes through a long region of mangrove. This consists of uniform flat country, mostly standing in brackish water and supporting a characteristic vivid green bush vegetation. Farther along the line, where the land is high enough to be reclaimed there is a mixed cultivation carried on by a moving peasantry. Some small banana plantations observed at this point were obviously suffering from a high water-table, and bore the characteristic symptoms in spindly uneven growth, with much leaf discoloration ; there were also cases of Panama Disease. This land was little more than reclaimed and the hollows all contained standing water. The soil of a yam bed close by was examined ; the surface soil appeared to be very good, rich in humus and of good texture, but about 4 to 6 inches down there was a quick change to a peculiar light yellow soft micaceous sand.

As we proceeded up the Valley other bananas were observed, many of which displayed some defect in general growth and vigour. A plantation near a limestone quarry was examined in some detail. This area, evidently at one time a bog or pan of some kind, had been recently reclaimed by drainage and planted with bananas. Some of the plants were making a strong growth, but on the whole the plantation was very uneven, indicating lack of soil uniformity or unsuitability of some kind. The soil was of greyish white colour, very close and compact in texture, and obviously in the need of aeration. Here the defects in growth had probably resulted from planting too soon after reclamation. A neighbouring area supporting much better bananas had soil of a much loamier nature. Forest soil nearby consisted of a dark loam, well supplied with leaf mould, underlaid by a yellow clay subsoil.

Farther up the valley an interesting riverside area was examined. This had supported bananas from 1911–1918, abandonment being attributed to Panama Disease. It had been allowed to go back into secondary bush, and during the present year it had again been cleared for bananas. Drainage was good and the young supplies were growing very vigorously. The top soil, on examination, was found to be a very open gritty sandy loam, at present well supplied with vegetable mould. It was underlaid by a gritty gravelly subsoil. Such soil and subsoil undoubtedly make for admirable rooting of the Gros Michel, but in a country of heavy rainfall, leaching of the essential minerals must be very rapid, while the humus supplied by the secondary bush will soon

be depleted. Thus, a soil of this kind shows two contrasting characters, namely, great fertility in its virgin state, and rapid exhaustion under single crop exploitation.

The 25-mile railway line terminates at Middlesex, an area originally planted up with Gros Michel, but soon abandoned on account of disease. This area showed a considerable variety of soil types, including a gritty yellow clay, deeply weathered, a red soil of the type seen in Guatemala, and an alluvial yellow brown silty clay. This variation is not surprising when we consider that this is the point where many of the tributaries meet to form the main stream, and also where the plain and hillsides meet. The red soil, of fairly extensive occurrence, had been weathered at several points to something resembling a laterite ; it has already been mentioned that such soils are avoided for banana cultivation in Guatemala. This formation was not alluvial in nature but appeared rather to consist of the original hillside material, weathered out *in situ* by the high rainfall. This type merged into the yellow clay—a resistant soil occupying the areas between the many streamlets, and as a result washed free of all the coarser and more friable materials. The valley bottom near by consisted of a stiff compact silty loam, probably acid, but with good qualities if suitably treated. In its present untilled state the compact texture would oppose root development. Surface drainage in these areas appeared to be good. An examination of the streams showed that these flowed clear and free of sediment over stony and sandy bottoms. The whole area of Middlesex has many springs and streamlets whose headwaters lie not more than 5 or 6 miles distant.

Other soils observed were poor and gritty, and would very soon be depleted of their foodstuffs. In one area an interesting soil profile was noted ; it consisted of a good surface loam, 4 inches deep, immediately overlying a silty yellow clay, the transition being clearly defined. The clay subsoil which had been thrown out of the ditches some two months before still remained unpopulated by the adjacent weed flora, indicating the presence of some markedly toxic substance.

In presenting these observations on the soils of Stann Creek it is not claimed that anything in the nature of an adequate field survey was made. There are, however, certain inferences which cannot be overlooked, especially in relation to broad scale agricultural exploitation. These may be briefly discussed as follows :—

(1) There are no extensive areas of ideal banana land in Stann Creek, and the soil, instead of being uniformly good as is usually thought, is, on the contrary, very variable and often poor. The various soils examined fall into two main categories :—

(*a*) Soils consisting of large particles, mainly coarse sand and grit. These are alluvial and have been left behind when the finer materials were washed down stream. If well supplied with humus they support remarkably good growth. This does not continue over many years, however, because the humus soon disappears, and the high precipitation causes extensive leaching. At the present time these soils occur in the loops of the meandering streams ; they give very good results the first year or two after planting but soon deteriorate when kept under a single crop with no attempt at humus conservation.

(*b*) In the second category are soils of a stiff compact nature which have been washed bare of all the more open and friable surface materials. Their cohesion and fine texture have enabled them to resist the violent denudation consequent on high rainfall. These soils are mostly found near the head of the valley, or on the hillsides flanking the river.

Thus, as Stann Creek is not a broad valley, the extent of alluvial soils of good texture is limited, and the general field evidence seems to indicate that the best potential soil material has been washed down the valley and deposited in the mangrove swamps or in the sea, leaving behind either coarse materials or stiff compact clays.

(2) From the brief examination described above it is clear that Stann Creek by no means shows a uniformity of soil type. In point of fact there are several soil types which quickly pass one into the other, thereby presenting considerable variation in field conditions. But, at the commencement of banana cultivation this does not seem to have been recognised, and following the general mode of procedure in Central America, bananas were planted broadcast. Considering the lack of soil uniformity, the absence of extensive areas of good banana land, and the presence of Panama Disease, the decline of the industry is scarcely surprising.

(3) The good banana land consists of alluvial soil ; some of the best is found in the triangular areas where the river forms a loop provided good drainage can be achieved. Thus a soil explorer following the river and not gauging the proximity of the clay hillsides might be misled into the belief that the potential banana land was extensive.

(4) Successful banana growing in Stann Creek will depend on the careful selection of the comparatively limited areas of suitable land. Taking the valley as a whole detailed agricultural reconnaissance and careful husbandry will be necessary to ensure anything more than transitory success.

Another visit was made to the Sibun River. At the mouth of the river there is the characteristic long mangrove belt, which gradually rises to an area where the soil consists of a stiff silty clay. This supports good sugar cane (peasant cultivation) but is not suitable for bananas. Higher up the valley are areas of Pine Ridge, sand and savannah—both probably highly acid, judging by the vegetation. On the whole, open loamy deposits appear to be localised and inextensive.

The soils of the northern plain of British Honduras (Northern River district) are calcareous marly clays. A certain amount of banana growing is carried on in this district, and I was informed that there was little Panama Disease. Unfortunately I was unable to make a visit to Northern River and therefore cannot supply data for contrast with Stann Creek.

The general impression of a visit to British Honduras is that a soil reconnaissance is desirable before further embarking on any large scale agricultural project.

## JAMAICA.

During my visit to Jamaica in July and August, I was able in company with Mr. F. E. V. Smith, Government Microbiologist, to visit most of the important banana growing districts and to observe the many aspects of cultivation. Jamaica has been described as an island of samples and this remark is applicable not only to the variety of soils on which bananas are grown, but it is also true of the many forms of cultivation. It is not proposed here to give a detailed account of the many aspects of the banana industry in the island. That has already been set out in Fawcett's book (The Banana) which covers all the major field operations practised in Jamaica at the present time.

The history and the present position may be summarised by the following two quotations :—" In the early stages of the industry in Jamaica, ' banana land ' was accepted to mean a soil in which without drainage, without tillage, and by a superficial process of clearing and, perhaps, burning before the suckers were planted, a good yield of commercial fruit was obtained by the grace of Nature alone " ; ..... and " If the working basis of the latest and most progressive cultivators be regarded, it would appear that a ' banana soil ' and a ' cultivated soil ' will soon be synonymous in Jamaica." Thus in the production of bananas, Jamaica stands out in sharp contrast to Central America. It has long since passed through the preliminary stage of soil exploitation and has now a deep rooted agricultural tradition with labour trained to detailed field operations.

The active interest which was taken in Panama Disease from the very outset in Jamaica soon materialised in the form of Plant Protection regulations. In 1910 a proclamation was issued forbidding the import of any portions of banana plants or labourer's implements from Central and South America and Trinidad, and during the following year a Diseases of Plants Law became operative to deal with possible cases of Panama Disease. The field measures adopted to combat the disease were most drastic and involved the destruction of all plants within a radius of one chain from the original infected plant. Since then the quarantine area has been reduced and in some parishes a " nine-root " treatment is the rule. In the writer's opinion this should be replaced by a " one-root " treatment to destroy infected material and prevent its use for replanting. As far as the merits of the quarantine regulations are concerned, when it is considered that *Fusarium cubense* can grow and spread through the soil it is obvious that the present " nine-root " treatment does nothing to destroy or control Panama Disease. Financially, the destruction of plants under the quarantine does nothing but magnify the loss.

At the present time there are many false ideas afloat regarding the virulence of Panama Disease. During my visit areas of good land were pointed out to me which were described as " abandoned on account of Panama Disease." Enquiry into the number of cases and the acreage showed, however, that there had been perhaps five or six cases per acre, i.e. five or six diseased plants in 350, or about $1\frac{1}{2}$ per cent. of actual disease. Now it must be recognised that this small percentage of disease cannot be regarded as *virulent*. It is true that there are a few areas where 10 per cent. of diseased plants have been found, but examination of the area showed that in all probability

it should never have been planted in bananas at all. Examination of the records, however, show that many areas of good land have been abandoned on account of a very small amount of actual disease.

In a report submitted to the Acting Governor of Jamaica in August, the following suggestions were offered for consideration :—

" (1) The present quarantine regulations entail considerable expense on the part of the Government, and cause considerable loss to the planter in respect of treatment, loss of land and fruit. From the point of view of modern fungal and soil science, the nine-root treatment does nothing to stop the spread of the fungus. It is suggested, that, at a suitable time, *the nine-root treatment should be replaced by a one-root treatment.* There is everything to be said in favour of a one-root treatment as it prevents the use of infected material.

" (2) If Panama Disease is cured it must be cured by treatment capable of simple agricultural application, and within the economic limits of the industry. All the evidence suggests that the disease is associated with lack of fertility and adverse soil conditions, such as acidity, bad aeration, water-logging, shallow soils, presence of toxic subsoil, etc. Each soil must be treated according to its own special requirements. As we are at present in a state of ignorance, due to lack of experimental evidence, regarding the conditions which make for the attack of *F. Cubense, it is suggested that greater freedom and scope be given for the purpose of carrying out critical experimental work in connection with progressive soil improvement and the treatment of diseased areas.* Of course it will be said that such work has been carried out with no result, but there is no published or other evidence to show with what accuracy or critical care the experiments were carried out. Unless the experiments are carried out under properly controlled conditions, they are useless. It should also be pointed out that such experiments are not of the ' hit or miss ' variety. Every experiment brings some new knowledge and while the disease may not be absolutely eliminated by sound agricultural treatment, it may be held in check to such an extent as to be no longer a menace.

" (3) It is suggested also that a constructive policy should be adopted with regard to improvement of agricultural methods, such as deeper cultivation either by fork or by the use of up-to-date implements, the appropriate use of lime from the many

sources of good lime throughout the island, and the conservation of soil humus by the use of cover crops. If some of the present expenditure on Panama Disease were directed into these channels, there is a strong probability that Panama Disease would be held in check, while the whole agricultural industry of the island would benefit by the better husbandry and improved soil fertility which would result."

In Jamaica very considerable progress in the practice of agriculture has already been made, but there are still many instances of good land which would be greatly improved by suitable treatment. On the other hand, there were several instances where considerable insight was being shown in the making and treatment of soils, in the opening up and improvement of land, and in the use of lime and cover crops.

## COLOMBIA.

To the investigator of banana problems, Colombia offers very considerable interest. Since the first recorded export of about 172,000 bunches in 1892, the industry has expanded as follows : 1,397,000 bunches in 1906 ; 4,902,000 bunches in 1911 ; and 10,870,000 bunches in 1926, when Colombia ranked as third in the banana producing countries of the Caribbean.

The banana land of the Santa Marta district of Colombia consists of an alluvial coastal plain, whose soil derived from the Sierra Nevada de Santa Marta has been transported and deposited by a number of parallel streams. The alluvial materials vary from gravels and coarse sands to very fine silts and clays. Chemically the soils are sound, being adequately supplied with all the essential minerals (with the exception of Nitrogen in some instances), coupled with a high lime content. The rainfall is limited and during the dry periods irrigation is the rule. Colombia is unique in that the occurrence of Panama Disease there has not been reported. Lastly it should be mentioned that good plantations of the Gros Michel have been established on a wide range of soils, from coarse sands, with very little binding matter, to fine silts of good physical texture. In many areas the soils are very good and suitable for bananas even without cultivation. This may be attributed to their good physical texture, the adequate lime content, and to the open sandy subsoil found in most districts. Yet, in Colombia, as in Central America, there are considerable areas of abandoned land and that even in the absence of Panama Disease. On the whole, the field problems appeared to the writer to be of a fairly direct nature. They include, in order of importance, high water-

table and drainage, soil aeration, and salting. Other difficulties are concerned with the maintenance of irrigation water, while the major calamity is undoubtedly the occurrence of an extensive "blowdown."

Colombia offers favourable conditions for studying the effect of bad drainage and water-soak on the growth of the Gros Michel, especially as the added complication of Panama Disease is absent. In one section a large area had, at one time, been abandoned on account of adverse conditions, but this has proved to be simply a case of drainage and already half of this area has been reclaimed. Here direct observations on water-soak can be easily made, because all gradations from bog conditions to well drained soil occur in close proximity. Typical uncomplicated water-soak in Colombia produces characteristic effects, to wit :—(*a*) the whole plant is stunted, (*b*) the leaves are of pale-green fading to dull yellow, sometimes with streaks along the veins, (*c*) the leaf-blade often breaks through halfway, (*d*) no Panama Disease symptoms external or internal, are present. Where a plantation dips to a water-logged hollow a gradation from tall healthy plants to dwarfed discoloured ones is the rule. Soil examination revealed good texture and suitability to strong root formation. Reclamation consists in opening up existing creeks, excavating broad drag-line ditches, and digging lateral drains so as to bring the water-table to at least three feet below the surface. Water-logged areas are easily recognised by the distinct semi-aquatic vegetation which they support.

Second in importance to drainage, and, indeed, directly related to it, is the problem of soil aeration. Soils of coarse texture or those which have long had adequate drainage need not be discussed at this point. They mostly prove fertile and consistently yield good fruit. There are considerable areas, however, where the soil is in distinct need of stirring and ventilation, the absence of which adversely affects the growth of the Gros Michel. A typical soil profile frequently observed was as follows :—on top there was a foot of grit, loam or soil of fairly good texture ; this was underlaid by a blue clay-like stratum, while at $3\frac{1}{2}$ to 4 feet down an open sandy layer was usually found. In various sections bananas had been planted on such land, and as a rule they showed poor lagging growth, a stunted appearance and bad colour ; sometimes the plantation failed completely or took 20 to 24 months to fruit instead of about 12. The major difficulty was fairly evident. When the planting material is set in the usual 15-inch hole, the young roots come almost immediately into contact with this stiff impervious unoxidised clay. The result is that they are usually

blackened and killed. In its original state the blue stratum has a clay-like plasticity, and it is often highly mottled with red ; if it is exposed for a few weeks, however, it undergoes a remarkable change. It weathers very quickly, there is a rapid colour change to brown, the gummy character disappears, and when crumbled between the fingers it is found to be in reality a fine silt. The highly coloured appearance and clay-like plasticity have evidently been imposed on the material by long compacting under water. During the weathering of such material it is clear that many important chemical changes are set in motion. What these are is not definitely known, but they are probably referable to the broad category of oxidisation. Many field observations indicate clearly that both in its original state and while the first stages of weathering are in progress, this stratum is distinctly toxic to the newly formed roots, thereby involving a general depression in all the growth activities of the young plant. Such land should obviously be prepared before planting.

Another field, examined in some detail, had been planted only one month after the completion of drainage operations. Practically all the young plants had a stunted yellow appearance, accompanied by a leaf scorch suggestive of chemical defects. Suckers dug up had a soaked appearance and were rotted and invaded by various putrifying organisms. As a rule the sucker was found to be absolutely encased in blue clay. Roots which had penetrated the clay were blackened and killed as if by toxicity, so that the general effect on the young plant was that of root failure and chemical injury. Where open drains occurred, however, it was found that this clay weathered out to a silty soil of good texture. Field experience shows that these soils slowly improve, but it is a question if, in the absence of adequate stirring and ventilation, they will reach their maximum productiveness for a long time. The best results will undoubtedly be achieved by ample aeration before planting.

The areas which have been abandoned on account of " salting up " occur in the Rio Frio district. This land, consisting of a remarkably good, free loam, lies only a few metres above sea level and is in moderate proximity to the coast. The area, arid in its natural state, was planted with bananas, but irrigation was insufficient and drainage was poor. After some years, by the concentration of salts at the surface, due to high evaporation and inadequate leaching, the land became " salted up " and banana cultivation has gradually receded. On inspection the soil texture was found to be excellent ; but on the

surface there was a powdering or caking of soluble crystals to such an extent that the only persisting vegetation consists of typical halophytes, including samphire, mesquite, and other leathery leaved and prickly plants. Farther inland where bananas still persist, the effect of salt land was seen in a general stunting of the plant accompanied by a dull-coloured marginal withering of the leaves culminating in a dead brown. There was no leaf breaking, and in general the appearance was that of chemical scorching. Similar areas of banana land in Jamaica were also abandoned on account of salting and this was again due to the absence of ample irrigation water and of suitable drainage. Such land can gradually be reclaimed by leaching given sufficient water and adequate drainage.

The incalculable factor in Colombian banana production is, of course, the blowdown. This is purely local in occurrence. It is the result of a violent wind storm generated in the hills, which, sweeping down on the plain causes a great deal of curiously localised damage. During my visit in August, following a blowdown, I was able to make observations on the damage sustained. The noticeable feature was that most of the destruction consisted in a snapping of the trunks, and not in a total uprooting of the whole plant. The latter is another indication of the general soil character which, for the most part, is of such a nature as to allow of good root development.

These observations touch on but a few of the many interesting banana problems of Colombia, a country of great interest and undoubtedly of great possibility.

## PANAMA.

In Panama, the modern banana industry, as in other Central American countries, began about the opening of the present century. For many years bananas have been the chief export and even at the present time, although production has greatly decreased, they still take first place among the country's natural resources ; thus of a total export trade of 3,530,800 dollars, in 1925, bananas were valued at 2,165,150 dollars. The original industry was centered at Bocas del Toro, but at the present time fruit is also grown for export in the Canal Zone, and in the San Blas district (East of Cristobal), while new areas are being opened up at Armila on the Caribbean Coast, and in the Chiriqui province on the Pacific.

Panama Disease was first recorded from Panama in 1903. A few years later it had caused great havoc there and also in Costa Rica. By 1920 several areas of 15,000 to 20,000 acres had been abandoned.

In 1926 alone a total area of 4,538 acres of Gros Michel land was abandoned, and it was estimated that a still larger area would go out of cultivation the following year. This country is, therefore, of the greatest interest to an investigator of Panama Disease. Popular accounts generally attribute to these lands enormous fertility and ideal conditions for uniform large scale production of bananas, while Panama Disease is regarded as the scourge responsible for all failures. To endeavour to assess the veracity of these ideas, and to obtain definite personal impressions the writer made a special visit to Panama in October.

*The Changuinola District.*—The original banana industry of Panama was centered at Bocas del Toro, from which fruit grown round the Chiriqui Lagoon and Almirante Bay was exported. The present centre, Almirante, lies on the mainland ; it has a well-founded United Fruit Company colony and is responsible for handling all the fruit produced in the Changuinola, Sixaola, and Talmanca districts.

On leaving Almirante for the Changuinola district* the railroad runs parallel to the coast and passes through low-lying bush country, partially occupied by small settlers who grow a limited amount of bananas, cacao, and household crops. The land is undulating and out-crops and cuttings reveal the presence of characteristic red and yellow clay.

Large scale production is first encountered in the vicinity of the Changuinola River. At this point the stream is broad and meandering, with many backwaters and lagoons. The large, approximately square, area through which the river passes—known as the Changuinola Division—is a great alluvial flat, very little above sea level, and subject to frequent inundation. At one time it was extensively planted in Gros Michel, but now, with the exception of a few outlying small farms near the hills, it has been completely abandoned for bananas, and has been replanted in cacao and coco-nuts, or left as pastures. The latter present broad and picturesque vistas. At the present time the cacao is not so good as it might be, and in general suffers from close planting and too much shade. Coco-nuts have been planted but with no great success ; they show defective growth and are subject to several diseases. Thus, at the present time, one can pass through practically the whole of the large Changuinola Division without seeing a plantation of Gros Michel.

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* By courtesy of the United Fruit Company.

Soils of some of the cacao plantations were found to be of good silty loam, and, I was informed, remained in good condition in spite of the heavy rainfall. Other soils examined were decidedly mottled. The whole of this area is subject to great leaching on account of high rainfall and flood. To generalise on the nature of these soils, however, is both difficult and inaccurate, since they have been laid down under varying conditions, by a river whose course has frequently changed during the formation of the alluvial plain. Changes in the direction of the river from time to time are reflected in the presence of many backwaters and lagoons. These may exercise a considerable influence on the surrounding district.

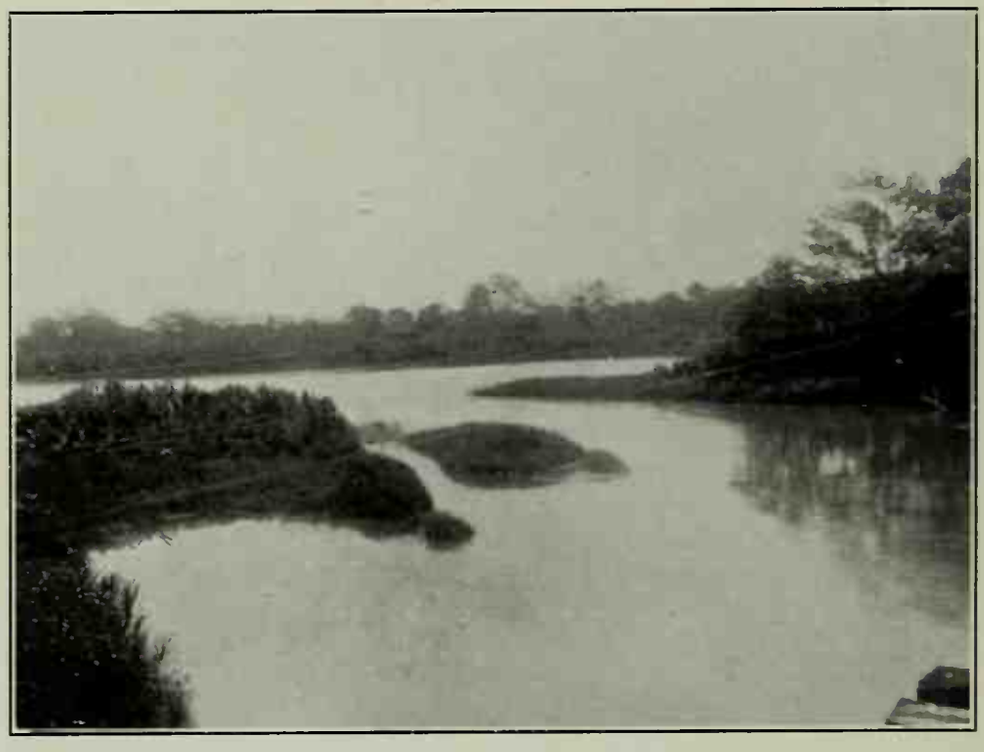

*Fig. 20.*—View from above of the Changuinola River and one of its tributaries, Panama. The flat alluvial banana land has been deposited by the successive floods of the Changuinola.

This extensive area, now well supplied with railroads, was felled and planted in the usual way, and it appears that most of the farms gave about 12 years of fairly good production before the major troubles set in. As far as the records go, they indicate that on those farms where general growth and production were good the rate of spread of the disease was slow. Where cultivation and production were poorer the disease is usually reported as having spread rapidly.

From the incomplete information gleaned on a brief visit, many conflicting pieces of evidence emerge, and it is necessary to disentangle and evaluate the many contemporary incidents as far as possible. Thus, as pointed out elsewhere, in the rush to open up large areas, diseased material was often planted on the best of land, but of course, with the lapse of time and change of *personnel* it is now impossible to estimate the extent and significance of such procedure. Another aspect, however, emerges from a study of the available records when

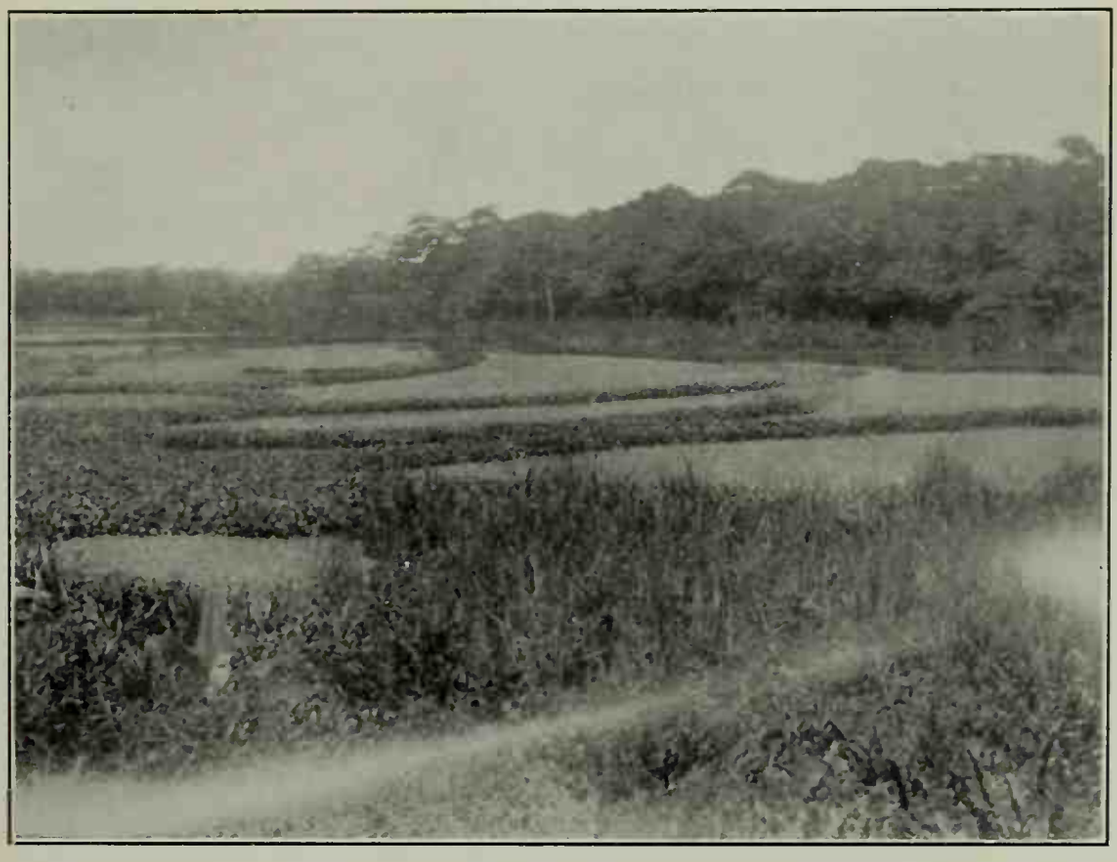

*Fig. 21.*—A picturesque backwater in the Changuinola banana country. During floods the river frequently changes its course, thereby forming lagoons and backwaters which influence the adjacent country.

read in conjunction with some knowledge of the behaviour of virgin land under a single crop. On many farms Panama Disease had been recognised for a long time. Its spread was noted as being slow or very slow. Then, after the land had been constantly under bananas for 10, 12 or 14 years, the disease is reported as having spread very rapidly. In the light of these observations it is clear that the spread of the disease presents two distinct facets, namely, the slow spread

*Fig. 22.*—Giant trees left standing in a newly opened plantation. Panama.

while the soil is still strongly influenced by its original virgin condition, and the rapid spread after 10 or more years when the original soil status has been greatly modified. Already there is a body of information which points to the fact that, with the exception of certain soils of remarkable staying fertility, a rapid deterioration is induced by single crop exploitation of virgin soil in the absence of cover-crops, rotation, cultivation, and general maintenance of food supply. The exact nature of this deterioration has not yet been determined. The general biological observation is, however, of some value. A soil originally supporting giant rain-forest trees, when planted out under a single crop for years on end must undergo marked modification. For the particular crop in question the soil appears to have decreased in fertility. In the writer's opinion this is an aspect that deserves attention in any discussion of large scale abandonment. It may be a factor that operates alone, or it may work in conjunction with the parasitic activity of soil organisms. Thus abandonment may be attributed simply to an accumulation of the specific parasitic organism in the soil, or it may be associated with factors which begin to operate when important departures from the original condition of the virgin soil have taken place.

The remaining banana farms in the Changuinola Division are privately owned. They occur on the outer margin of the large plantations and occupy areas which were formerly rejected for banana growing. One of these was visited and was found to be rapidly degenerating, yet only some five years ago it had been virgin land and had produced well for the first few years. Panama Disease was an important source of loss, but the irregularity of the plantation was further accentuated by water-soak caused by the high water-table. The soil, a silty loam, was found to be badly mottled, while the general upkeep was negligent. The abandonment of such a property would be attributed to Panama Disease, but, while the latter is undoubtedly significant, there are clearly other equally important adverse factors at work. Another small plantation privately owned had recently been opened up on the edge of untouched virgin forest. Here one was able to observe the enormous stature of some of the trees. On penetrating into the forest it was found that, owing to the shade, there was very little undergrowth ; a soil profile showed surprisingly little surface mould, while the influence of humus was decidedly limited.

A visit was next made to the collection of banana and abaca varieties belonging to the United Fruit Company. This large and

interesting collection was made with a view to breeding an immune variety to replace the Gros Michel, but so far nothing of direct commercial value has resulted. The collection is planted on land badly infected with the Panama Disease organism, and in contrast to the immune varieties the susceptible ones can be seen at a glance. Thus one is led to recognise the fact that, while there may be some external soil condition which militates against the resistance of the Gros Michel, the land is yet sufficiently fertile to support good stands of other varieties. Such observations are indicative of the importance of genetic constitution.

*Fig. 23.*—A characteristic view of the Sixaola River (Panama–Costa Rica). The river meanders across the plain, forming flat alluvial stretches by a succession of silt depositions.

*The Sixaola Division.*—On the way from the Changuinola to the Sixaola district the railway passes through the San San Swamp. This is an extensive area of low-lying land, covered with aquatic vegetation, and sometimes flooded to such an extent that the railway becomes impassable. Bananas growing in the vicinity of the swamp exhibit the adverse effects of the high water-table.

After crossing the San San swamp the railway proceeds to Guabito, a large Fruit Company settlement, which serves as the centre for the activities of the Sixaola Division. The latter is an extensive area, and includes plantations on both the Panama and Costa Rica sides of the Sixaola River.

A visit was made to one of the few remaining banana farms on the Panama side. This had been planted out in 1919 on virgin land and had produced well until 1923 when rapid deterioration set in. Since then it has been completely abandoned, and is now in rough pasture.

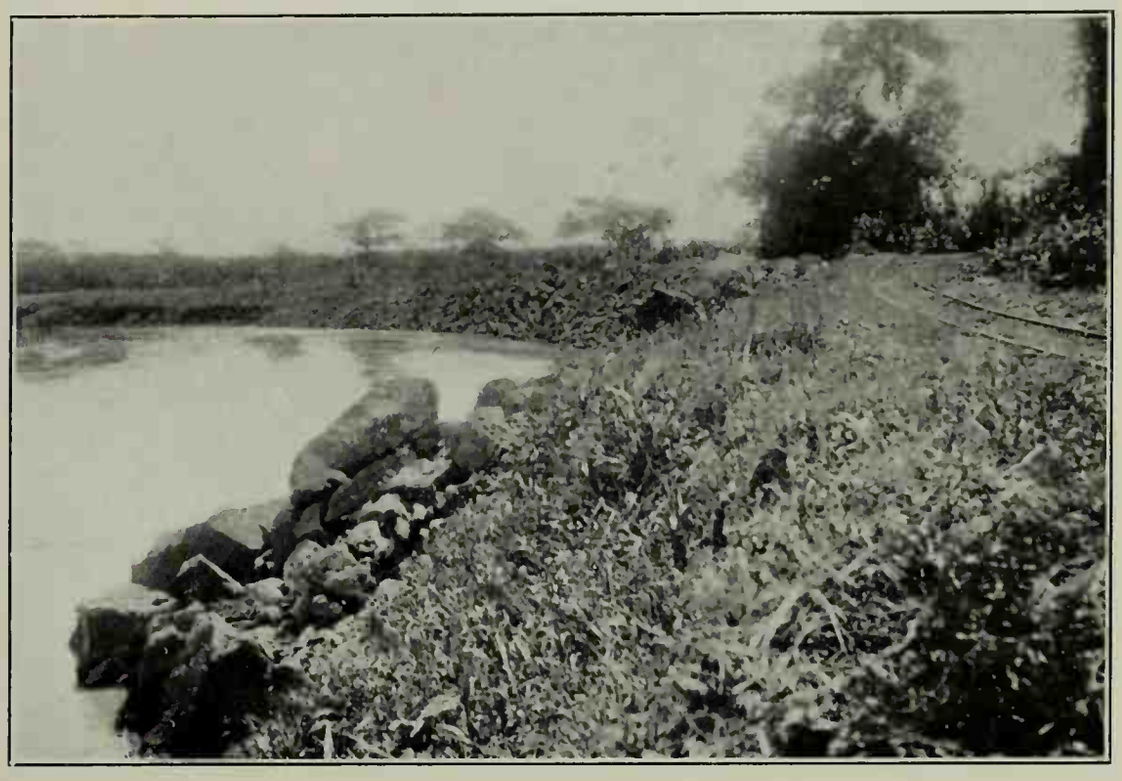

*Fig. 24.*—A large stone embankment constructed at a bend of the Sixaola River to prevent a change of course and the consequent flooding of cacao plantations.

As usual it was attributed to Panama Disease or "disease." Examination revealed several interesting points :—

(*a*) The top soil was in bad condition, being lumpy, hard and baked ; it also suffered from shallowness.

(*b*) The subsoil was a sticky mottled clay.

(*c*) The water-table was high.

(*d*) The secondary vegetation was semi-aquatic, consisting of characteristic grasses, sedges and aroids.

In other areas of this farm where bananas were still growing, or where abandonment was of recent date there was evidence that water and bad maintenance were factors for abandonment in addition to Panama Disease. The soil was again mottled and in poor condition with a highly impervious subsoil.

In the Sixaola North Division (Costa Rica) the river is sinuous and meandering while flooding, bursting of banks and changes in the whole course have not been infrequent. On passing through this section of country one encounters many lagoons, creeks, backwaters and dried-up river courses. As a result of this type of river action

*Fig. 25.*—An abandoned area, Sixaola Division. The land has been allowed to go back into secondary bush and grass, and only occasional clumps of bananas remain.

the soils are exceedingly varied. They include all grades of alluvial material, in different combinations according to the mode of deposition, and to the nature of subsequent flooding. There is thus no uniform alluvial soil over this section and the variation in the vegetation from area to area may be taken as indicative of the many different growth conditions.

Taking this region as a whole the farms generally lasted from ten to twelve years, after which they were abandoned on several counts.

At the present time practically the whole area is in cacao—an enterprise which has not yet proved very profitable. Generally surface drainage is good, but local drainage is poor on account of the compactness of the soil. This is now being improved by the growth of a leguminous tree used as a shade for cacao.

It is a strange fact that one may now pass through this large division and only occasionally see small plantations of bananas. One of the remaining cultivations, the property of a small fruit company, was visited. The plantation was found to be poor and uneven, and

*Fig. 26.*—Abandoned bananas overgrown by secondary vegetation. After a few years the bananas practically all disappear, and are replaced by a rather poor type of secondary bush. Sixaola Division, Panama.

the fruit mediocre. The soil was a sticky marl-like clay, low in humus, and as a whole of distinctly poor quality. Panama Disease was fairly abundant. A newly opened section, some eighteen months old also showed very indifferent growth. The humus of the virgin forest had only influenced the soil to a depth of about 2 inches, below which was an intractable sticky clay. Under these conditions the slow uneven growth of the plantation was not surprising. This, however, is but one of the many instances where cultivation has been attempted on

unsuitable land. Such a plantation will inevitably be abandoned in a few years. Fruit, however, is so scarce that any production, no matter how fluctuating, is acceptable.

In contrast to these conditions on clay land, another area was inspected where Lacatans were being used as a shade for cacao. The soil was very poor and gravelly and the resulting growth was feeble.

On the whole, the Sixaola Division is much less uniform than the Changuinola Division. Enough has been said to indicate that the uniform fertility attributed to these two districts does not represent the whole truth.

*Fig. 27.*—Final stages in the disappearance of bananas in abandoned areas. The stools are smothered by grass and are finally overgrown with vines. Panama.

*The Talamanca Division.*—After the abandonment of the Changuinola and Sixaola Divisions for banana growing, the Talamanca Division was opened up. The major operations began about 1920. Before then only a few private planters had occupied land in this area, but the pressing need for fruit led to large scale operations in this outlying section. Already many of the plantations have been abandoned, and indications are not lacking that the whole Division

will soon share the fate of Changuinola and Sixaola. But this is not surprising, since much of the land is quite unsuitable for large scale production, while the nature of the country is such as to make for high overhead expenses.

A few observations on the nature of this country will make matters clear. The whole area lies close to the hills and is greatly dissected by many streams. These are swift flowing, and with the high rainfall and drainage from the hills they rise quickly and cause important

*Fig. 28.*—A typical example of the many dried-up river courses in the Sixaola Division. The country, far from being uniform has been formed under a variety of conditions.

floods. The result after long and continuous erosion is that most of the friable sandy and silty materials have been carried off and deposited in the alluvial flats lower down, leaving behind only the more resistant and intractable clay soils, or gravels and grits. Thus the soils of Talamanca are both varied and poor. Here and there good pockets occur, which, planted up originally, gave satisfactory results and suggested that Talamanca might prove to be good banana country. It appears that extensive field operations were commenced

with only a meagre preliminary soil exploration. On several counts it has proved a very unsatisfactory division. As a result of the divided nature of the country road-making and bridge-building are heavy oncosts, while the rapid floods are a cause of constant destruction of bridges, whose upkeep is expensive out of all proportion. These, together with the short-lived nature of the plantations, militate against the success of this enterprise.

Some areas were quickly affected with Panama Disease, others were so little suited to the Gros Michel that the plants grew badly and did not even shoot. As indicated above the most productive soils are found in localised pockets. Such an area is clearly more suited to detailed working by small owners or a localised peasantry than to large scale uniform exploitation.

*The Canal Zone.*—In addition to the production of bananas in the Province of Bocas del Toro, the larger fruit companies also purchase and ship fruit from Cristobal. This is grown round the Gatun Lake, and in the San Blas district to the east. This enterprise is a result of the scarcity of fruit consequent on the large abandonments described above.

The banana-growing areas in the Canal Zone are situated round Gatun Lake and along the upper reaches of the Chagres River. These plantations are small and localised and for the most part are only accessible by canoe or motor-launch. Most of the fruit is rather small and of indifferent quality, but for want of better is actively competed for by different companies, an important factor being the possession of a fleet of suitable launches and barges. Through the kindness of the United Fruit Company I was able to make observations on plantations on the shores of Lake Gatun and along the banks of the upper Chagres River.

At the present time banana-growing round the shores of Gatun Lake presents some rather unusual features. On account of the impounding of the Chagres River in Gatun Lake to furnish water for operating the locks of the Panama Canal, cultivation is now of necessity limited to the high ground and hilltops which rise above the new water level. Most of the plantations occur on the typical red and yellow clay soil common to many of the low hills of Central America. For banana-growing, as pointed out elsewhere, this soil is distinctly poor. Consequently, the plantations are short-lived, and

after producing for four to seven years they are allowed to go back into bush. Panama Disease is of frequent occurrence and is scattered through all the plantations.

The average farm, of about twenty acres, is rented cheaply by a peasant proprietor. Plantations occur here and there on islands (hill-tops), valley tops, and hill-sides. There are many of these round the Lake so that the total collection of fruit lies between one and two million stems per annum. The general upkeep is bad, little bushing is done, and as a rule areas are abandoned after two, three or four

*Fig. 29.*—A typical example of peasant banana-growing on one of the islands, Gatun Lake, Canal Zone. The Island was originally a hilltop, the soil is poor and plantations are accordingly short-lived.

crops—in fact, it is a typical example of shifting peasant cultivation. Near the occasional lime out-crops the soil is better so that some of the farms may last for seven years, and, I was informed, may give 70 per cent. of 9-hand bunches. In this region then we have a typical case where land has been abandoned, not on account of disease, but because of the rapid deterioration of indifferent soil in the absence of good husbandry.

As the launch proceeded up the Chagres River to Santa Rosa, a primitive settlement where some fruit is collected, localised banana plantations were observed on the hill-sides. The river was in flood at this time and it was observed that instead of carrying along heavy silt and sediment it was yellow with clay washings. This may be taken as an indication of the nature of the residual hill-side soil, depleted by long continued and extensive denudation of all its open friable materials.

*Fig. 30.*—A view on the Upper Chagres River, Canal Zone. The dead stumps of large trees indicate how the land has been flooded up by the formation of the dam. There is a considerable amount of banana cultivation along the new banks of the river, i.e., high ground not usually pressed into service when bottom lands, valleys, and lower hill slopes are available.

## CONCLUDING OBSERVATIONS.

Although the data set out in this report are necessarily incomplete, yet certain broad generalisations emerge which are worthy of consideration:

(1) The old idea of the optimistic planter that all virgin soils are necessarily highly fertile must give way, after many costly mis-adventures, to a recognition of the fact that many areas are not suited to large scale exploitation. Where conditions have permitted of the latter the procedure has had the justification of financial success,

and large organisations, such as the United Fruit Company, have proved not only important agricultural pioneers, but also a great force in introducing and advancing civilisation. On the other hand, if the same methods are attempted in unsuitable areas, diseases and difficulties accumulate, and, sooner or later, abandonments result. These usually involve considerable capital loss. Thus it would appear that some areas, such as Stann Creek, Talamanca, and the Canal Zone are at present better suited to detailed selective cultivation by small private owners or a localised peasantry, than to the expensive and elaborate machinery involved in large scale exploitation.

(2) When new lands for large plantations were being sought out at the beginning of the modern banana industry, the great value of alluvial areas was soon recognised. Often the large tracts of country were very incompletely surveyed, thereby detracting from the general efficiency of field operations. One scheme of planting was used throughout, and on the whole the general botanical and agricultural knowledge brought to the task left much to be desired. Experience and detailed observation, however, have shown that alluvial plains have by no means uniform texture or fertility throughout. Some areas are so fertile that they appear to be able to support bananas almost indefinitely, but in close proximity other soils are found whose life, in the absence of detailed treatment, appears to be distinctly limited. The principle adopted in the early days to test the suitability of new areas was to fell the forest, plant and await the result. Failures on account of sourness, heavy clay, high water-table, poor soil, bad material, etc., were common, and the land was abandoned often without a second planting. Real insight into the problem was thus replaced by an expensive and destructive test. The justification of this procedure lay in the extensiveness of the field operations, and in the general success achieved, while agricultural and economic conditions were such that it was easier and cheaper to exploit new areas than to attempt to improve indifferent plantations by detailed treatment.

Thus, although large scale field operations have been in process for a quarter of a century or more, little has accrued to our general fund of agricultural knowledge from these sources. After a longer or shorter period of intensive single crop exploitation comes the inevitable abandonment. This may be due to deterioration or disease. The alluvial land is first used up and then there is a retreat to the untouched hillside areas, where the life of plantations usually proves to be of still shorter duration.

At the present time these are the usual pioneer phases in the agricultural development of new lands in Central America. It is perhaps the only method possible under existing conditions, and the procedure has many praiseworthy and justifiable attributes. At the same time giant forests are destroyed ; the native fertility of the soil is exploited to the utmost, and little or no effort is made to maintain or replenish it. But judgment of these matters is no easy task, and it must be left to the long arm of time to assign these agricultural methods to their proper category.

(3) These observations indicate the need for careful soil exploration, if failures due to choice of unsuitable land are to be reduced to a minimum. The variable nature of alluvial soils in certain large areas has been discussed at some length. Emphasis has been laid on the importance of studying river action where floods, changes in course, silt deposition, and erosion, are still operating vigorously. It has been shown that the resulting soil variations make for important differences in growth conditions in areas where uniform fertility might be expected. Detailed study of river action, then, may prove to be an important criterion in the selection of new land.

(4) To assess the importance of Panama Disease is now a task of the utmost difficulty. Where records are available, as in Jamaica, it is clear that the disease is by no means the most important limiting factor. In St. Lucia, where a banana industry collapsed, the failure has been attributed to insufficient finance. In Colombia, there is no record of Panama Disease yet considerable abandoned areas occur. In Central America, however, the problem is complex, and it is difficult to determine the importance of the several adverse factors which may be in operation at the same time. Causes of abandonment include :—

(*a*) Destruction by the activity and spread of the Panama Disease organism ;

(*b*) loss resulting from the use of diseased or defective planting material. There is a difference between this and the above ; this factor has an added significance in that, owing to the prestige of the disease, most areas where it had once occurred were never replanted ;

(*c*) adverse soil conditions, which include sourness, intractible sticky clay, high water-table, insufficient ventilation, and leaching of open soils;

(*d*) soil deterioration which sets in after four to seven years on poor soils, ten to fourteen years on medium soils, and twenty or more years on good soils, in the absence of good husbandry, rotation and detailed agricultural treatment ;

(*e*) poor production and bad upkeep due to general soil inferiority and undiagnosed factors.

Any of these alone or together may ultimately be the cause of abandonment. To the man in the street, however, " abandonment " in Central America and " Panama Disease " or " disease " are practically synonymous. The erroneous nature of this impression has frequently been pointed out in this report. That Panama Disease is very important cannot be doubted, but our knowledge is not being increased or a remedy brought nearer by overstatement or the propagation of misconceptions. In short, in any attempt to bring back abandoned areas into cultivation (other than by the use of an immune banana) there are clearly two distinct, but probably inter-related, aspects, namely the treatment of disease, and the recovery and maintenance of soil fertility.

(5) As these researches are directed ultimately towards economic ends, and as several different political interests are involved, it appears to the writer that there are many problems and issues worthy of the careful attention of a suitably equipped economist.

# APPENDIX.

## ST. LUCIA'S BANANA INDUSTRY*

BY

E. A. WALTERS, F.R.H.S., F.R.MET.SOC.,

*Agricultural Superintendent, St. Lucia.*

The purpose of the present paper is to provide a connected account of the inception and development of commercial banana planting in St. Lucia, with comments on the methods employed (1).

It is hoped in a future paper to give a description of the reactions of the soil and flora observed to take place in changing from a natural forest vegetation to a cultivated pure crop such as bananas, and the observations to be set forth therein will be found to have an important bearing on tropical agriculture in general. The present paper acts as an introduction to these observations.

The Gros Michel banana trade would be an attractive proposition were it not for the heavy losses suffered in conducting plantation work, when complicated by the presence of Panama Disease. The following information, based on the writer's actual participation in all phases of the industry, includes an account of the work done locally on Panama Disease and should assist in establishing the economic value of certain practices in connection with the attempted control of this disease.

### Origin of Banana Industry.

St. Lucia, like other islands with a similar climate, had for some years previous to 1922, conducted a variable export trade in several varieties of bananas, chiefly the Short Fig or Governor banana, *Musa Cavendishii*. Paxt., the Bout Rond or Giant Fig and the Gros Michel or Martinique Fig. The principal market was Barbados, whence the fruit was shipped by sailing sloop.

Towards the end of 1922, a proposal for the development of large scale banana cultivation was received from the representative of certain fruit interests in the United Kingdom. This proposal was favourably received by the local Government and special facilities were granted, and an area of 200 acres of Crown land in forest was purchased by private interest vested in the Swift Banana Company, and the necessary steps were taken to enrol labourers for clearing and preparing the land.

The area acquired was situated about nine miles along the Castries-Dennery Main road and at an altitude of about 400 feet at a point where the forest reaches down to the road, the site was thus readily accessible.

The rainfall of this area averages about 100 inches yearly, and the soil when cleared from forest, is seen to be covered by a layer of decayed forest humus which readily desiccates on exposure. The soil itself is a yellowish-brown clay loam tapering off into hummocks of a red lateritic clay, and responds to careful cultivation. The contour of the land is of a rugged nature, consisting of steep ridges and folds enclosing narrow valleys with a few moderately smooth slopes.

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## The Commencement of Planting.

Preparations for planting commenced early in 1923 and consisted of felling the forest trees, some of which furnished useful building timber and roof shingles ; but the greater proportion of the fallen logs were left where they fell or merely moved aside to allow of planting. The herbaceous undergrowth was burnt or cutlassed down, and lining and holing was commenced. At this stage the local Agricultural Department was called in to assist, and remained in co-operation with the Banana Company until the work was brought to an end by the dissolution of the Company.

The planting material was collected from both the large and small surrounding planters' holdings and consisted of sword suckers and bullheads of Gros Michel stools, being paid for at the rate of three cents per bullhead. About 90,000 plants were thus established in an area of 15 acres by the end of 1923, the actual planting having been commenced about April of that year.

One of the first steps taken by the local Department was to inaugurate a system of inspection of all planting material, at this time principally directed against the banana weevil *Cosmopolites sordidus*, Germ., and the banana borer *Tomarus bituberculatus*, Beaud., as these root pests were being found in a rather large proportion of the material supplied for planting.

The bullheads and suckers were treated by clearing away the loose trash and broken leaf bases, and by paring the roots, the plants being then soaked in lime-water for 48 hours to destroy any concealed larvae and eggs.

Plants were spaced at a distance of 6 feet each way to form a nursery to give bulk of planting material ; when planted out in the fruiting areas the plants were spaced 12 feet by 12 feet.

The labour utilised throughout the work consisted of the local West Indian native, generally illiterate, and with crude ideas as to the value of disinfective and control methods, but a good mechanical worker. Both men and women were employed at the rate of 1*s*. 6*d*. and 10*d*. to 1*s*. per day respectively, at which rates ample labour was available.

Supervision was exercised by the more intelligent native overseers or " drivers," under the control of coloured assistants who were responsible to the European Manager.

## Occurrence of Panama Disease.

The first three cases of Panama Disease were found in January, 1924, the plants infected being stools of about 7 to 8 months of age and situated on a slope in rather wet soil. The principal symptoms consisted of external yellowing of the lower leaves, and an internal yellowish-red discoloration of some of the vascular strands. In later cases where plants were more advanced in growth, splitting of the stem and some breaking of the petiole of the lowest leaf was observed, these latter symptoms, however, were never really pronounced nor general and were usually found in conjunction with borer and weevil attacks, i.e., severe dislocation of the food supply and ingress of bacteria to the vascular tissue. These symptoms differ somewhat from the published accounts, and will be discussed in the notes on soil conditions.

## Measures taken against Panama Disease.

The measures taken to control further spread of the disease come under four headings :—

(i) Treatment of infected areas.

(ii) Improved selection of planting material.

(iii) Survey of the distribution of Panama Disease.

(iv) Propaganda.

(i) *Treatment of infected areas.*—In order to obtain the best advice possible, a visit of the Mycologist of the Imperial Department of Agriculture was arranged. Specimens of the diseased plants had already been submitted for examination and were reported on as showing characteristic symptoms of Panama Disease. The visit of the Mycologist took place in August, 1924, and an inspection of the area was made. A report was then furnished giving the precautions necessary to reduce infection, viz., (*a*) by firing the infected clumps and digging out and burning the diseased plants, and destroying the contacts within a radius of 22 yards, (*b*) by the disinfection of tools and the isolation of the infected areas.

The details of destruction of plants and disinfection were well adhered to and were generally carried out under the supervision of the Officers of the Agricultural Department.

The isolation of infected areas, however, was not complete owing to the difficult nature of the ground, and to the fact that the labourers did not regard the prohibited areas with the necessary respect.

(ii) *Improved selection of planting material.*—Selection of planting material was further improved by a method worked out by the writer, this consisted of the sectioning or quartering of the bullheads, which were then examined on both surfaces, and also on the top where the central bud had been sheared away. The sections were then dusted with wood-ash, and in some cases soaked in lime-water to destroy weevil and borer.

By this means it was found possible to reduce considerably the amount of infected planting material, and the method was adopted both in the plantations of the Swift Company and other banana cultivations which were springing up throughout the island, working in co-operation with the local Department.

The areas planted on this method were found to give an incidence of one diseased plant per 1,000 as against one per 100 in the unsectioned plants, the rate of spread was accordingly reduced and a longer life was possible for the fruiting plantations.

(iii) *Survey of Panama Disease, and legislative action.*—A survey of the distribution of Panama Disease throughout the Colony was made about this time, the results showing a scattered infection in practically all the estates on the leeward coast which are readily accessible and open to frequent traffic. On the windward coast little banana cultivation had been carried on in earlier times, and estates in this area showed but few Gros Michel and no cases of disease. One case of disease was found on an estate situated midway on a road running from coast to coast, indicating that Panama Disease was more widespread and of earlier origin than had at first been believed.

It thus became necessary to examine carefully every prospective banana cultivation, both with regard to the existing plants, and also to go into the history of the estates in order to determine whether Gros Michel had been planted in earlier times, and had

disappeared owing to Panama Disease. In this way much interesting information came to light, and the peasants were often of help in indicating that a " malade " of the Gros Michel had become a part of their traditions. A striking case of the replacement of the susceptible Gros Michel by an immune variety occurred on an estate near Castries, from which a regular fruit trade with Barbados had been maintained, the total absence of the valuable Gros Michel was therefore remarkable and on research it became evident that this variety had died out from disease, and had been replaced by the Bout Rond—a " round end " banana of a somewhat soapy consistency and of a less delicate flavour. This variety was later identified as similar to the Giant Fig of Grenada.

Following the completion of the survey of disease, regulations were enacted to enforce destruction of bananas infected with Panama Disease and the treatment of plants attacked by weevils and borers. The movement of planting material was also prohibited except by permit of the Agricultural Department, following an inspection of the estate in question.

The Department was allowed to train two men as travelling inspectors of banana cultivation, and these men rendered valuable assistance in recording outbreaks of disease, and by carrying out actual treatment of diseased plants. Altogether 28,831 diseased plants were treated during the period 1925 to 1928, mainly by the officers of the Agricultural Department. It may safely be said that the attitude of the peasantry has entirely changed owing to the educative effect of the inspection service, and the peasant now realises that disease is a condition brought about by some destructive organism and not the wilful act of a far-seeing Providence.

Information was obtained as to the total distribution of all banana crops and of projected crops. The diseases were noted, and the accessibility of land suited to bananas was recorded for future reference. This information has proved valuable both in regard to banana cultivation and to other crops which are being substituted for bananas.

(iv) *Propaganda.*—Planters and others were instructed in the symptoms of Panama Disease, the treatment of diseased plants, and the methods of planting. Meetings were held at various centres where specimens of plants were exhibited, and a leaflet, *The Control of Panama Disease,* was printed in simple language and distributed throughout the Colony ([2]).

## Frequency of Panama Disease.

On checking up the information obtained on the survey a fairly definite idea was obtained of the frequency of cases of Panama Disease. Infection in the S.W. area of the Colony was at the rate of 0·7 per cent., and for the N.E. area was 2·5 per cent., whereas the lands of the Banana Company gave a range of 0·5 per cent. to 20 per cent. infection in the older areas.

## Soil Conditions and Panama Disease.

Judging by the few published accounts dealing with soil conditions and Panama Disease, there appears to have been little work done on the types and conditions of soil in which Panama Disease flourishes, as compared with the types of soil where the fungus can be held in check, such as the irrigated lands of Jamaica and Columbia.

It is therefore of interest to record certain detailed observations with regard to the soil medium and the reaction of bananas to varying soil conditions. One of the most striking effects was noticeable in bananas planted towards the base of the slopes, these grew vigorously and produced good bunches, whereas plants on the tops of ridges showed dwarfing effects, yellowing of leaves, and produced only poor fruit. These exposed plants gave a poor rotation of fruiting stems and suffered from drought, brought about by the complementary factors of leaf splitting, an inferior type of soil, and irregular water supply.

On the other hand, the modifying action of windbreaks with the improved soil conditions found near by, was evidenced in the vigorous growth of the plant and the absence of leaf splitting, humus was conserved and little leaching appeared to take place.

The following observations deal with two distinct types of soil :—

(I) *Soil Conditions in the Nursery—Ravine Poisson.*

The soil here at the time of planting, might be termed a virgin soil, undisturbed by earlier cultivation and bearing large forest trees forming the closed tropical rain forest vegetation with a well developed canopy.

On removal of the timber by felling, and within 6 or 8 weeks a crop of soft weeds covered the ground forming a transition stage, preceding the establishment of the larger herbaceous plants.

The soil consisting of a brownish-yellow clay loam covered by a loose layer of forest humus about three inches deep, this covering had become matted by surface roots and was not well decayed. The soil when cut in profile showed as a smooth cheesy clay loam in which aeration appeared to be defective as depth increased, the upper six inches being somewhat improved in texture by decaying roots. The soil puddled readily when worked in wet weather but responded to aeration and applications of lime by changing in colour from brownish-yellow to brownish-grey, and by forming a definite crumb structure.

This type of soil under wet weather conditions became puddled and needed extensive drainage, in the lower areas the soil was never really dry and the bananas never suffered from drought.

During dry weather the soil cracked readily causing drought conditions, particularly along the ridges.

(II) *Soil Conditions on the Hill Slopes and New Areas—Mt. La Combe.*

Soil conditions in the new upper areas along the slopes of Mt. La Combe were notably different from conditions in the lower land and nursery.

The soil here had supported a similar forest vegetation to that already described, but when examined in profile showed a distinct stratification formed by a superficial layer of humus resting upon a bed of yellow clay, in which there appeared to be no admixture of the overlying organic matter. The soil was naturally stiff and difficult to work, readily becoming sticky in wet weather. Dry conditions were never observed owing to the continous seepage of surface water from the upper slopes.

This is a type of soil which must be worked, it requires extensive drainage and applications of lime, otherwise it deteriorates.

## Root Conditions.

It is an interesting fact that the majority of the banana stools examined showed only a superficial root system.

Under soil conditions No. I the rhizomes were fairly deeply embedded in the soil, and possessed a few strong feeding and anchorage roots, most of these being in good condition.

Under soil conditions No. II the rhizome was less deeply embedded, and root penetration in the clay was remarkably poor. The feeding roots were scanty, and blackened for most of their length, and the absorbing rootlets appeared to die back at frequent intervals, whilst main roots had a water-soaked appearance.

In view of these defects it is a remarkable commentary on the vigour of the banana plant that bananas under these conditions gave much better returns than under soil conditions No. I, but it is doubtful whether plants could long survive such root reduction without serious loss of vigour and depreciation of bunches.

In utilising such primitive soil it should be a first charge that cultivation should be maintained and the physical conditions of the soil improved, as the small amount of available land restricts the grower to a limited area. This is in contrast to the methods employed in Central America where large areas of land are available ; in such conditions bananas are planted in holes opened through the cutlassed bush, and after taking the first few crops, these areas are abandoned for new ones planted on a similar method ([3]).

## Disease Effects.

Plants infected with Panama Disease were in close contact with apparently healthy plants, which after a period of two years still exist and continue to fruit, although neglected, and it is interesting to note that recent observations show that many stools in close proximity to earlier sites of disease exhibit no symptoms of disease, and this after the wettest season for 10 years (June to November, 1927) followed by a short but severe drought (January to February, 1928). Such weather conditions are entirely in favour of a rapid extension of Panama Disease.

It was also noticed that Panama Disease appeared quite frequently as scattered cases, and not often as an extension from a central point ([5]). Further it should be mentioned that the external symptoms of Panama Disease showed certain differences from the published accounts.

A point which needs emphasising was the condition of the water-soaked lateral roots, where these had died back after penetrating a short distance into the soil. This condition was not confined to diseased plants.

## Extension of Areas, Roads, and Transport.

A considerable impetus was given to banana cultivation as an estate crop, by the information given out by the Banana Company to the effect that banana contracts would be made with estate holders for a specified term to provide for the supply of Gros Michel of 7, 8 and 9-hand bunches at stated periods. As a matter of fact this form of contract was not regarded with favour by most planters, since the contract bound the planter to a five-year period during which time he should deliver his fruit only to the Swift Company. None of the contracts were therefore taken up and bananas were later collected by cash purchase at pre-arranged depots.

Bananas were established in several adjoining areas in the Cul-de-Sac and Roseau valleys, in all about 50 acres, which were being developed by local sugar interests. Development in other parts of the Colony was mainly evidenced by gradual extensions of the Gros Michel stools already present, particularly by small planters. An estate of 700 acres had been acquired by the Banana Company and was being rapidly converted from cacao to banana cultivation ; and by purchase of other land adjoining this property and the original cultivation, the whole area became linked up to form a continuous estate which was all to be planted up in bananas, mainly Gros Michel.

A system of roads was driven through this area to allow of motor transport, horse and donkey transport, and as highways for labourers. One ton Graham trucks were subsequently imported for the transport of bananas, the loading capacity being 100 bunches per trip. Meanwhile, the Agricultural Department continued to act in an advisory capacity, special stress being laid on the need for soil conservation. This included the provision of cover crops such as *Canavalia ensiformis*, the retention of belts of the existing forest to act as windbreaks, the extension of the drainage system by contour methods, and suggestions for pruning. With regard to pruning it was found that the average stool should consist of a fruiting stem about 11 to 13 months old—a large sucker about nine months old, to form the next bunch—and a medium sucker of three months, with two buds as followers.

This was the general character of work carried out through all the banana cultivations, in addition to the form of police-work entailed by the inspection service.

### The Position of Panama Disease at the Time of the Fruit Shipments.

Panama Disease had in the meantime rendered the original nursery of the Banana Company unprofitable, and this area was accordingly abandoned ; planting continued vigorously in the new area consisting of a block of 5,000 acres of forest. These new forest lands gave very good bunches and continue to bear bananas to the present day. The cacao estate already mentioned gave very good returns during the first crop, but succumbed rapidly to Panama Disease during the second year of planting, and it became evident that the soil was thoroughly infected with the fungus, which had no doubt persisted from scattered clumps of Gros Michel used as a secondary crop in cacao.

Some of the affected areas were being replanted with Short Fig, Bout Rond, and the Apple banana (Fig Pomme) a variety somewhat similar to the Bout Rond but with a hard centre. This variety rapidly died out from Panama Disease, and little use was made of the other varieties for shipping purposes.

At the time of the regular fruit shipments, the total area under the control of the Company was about 6,000 acres of which about 1,800 acres had been planted up, and 250 acres had been thrown out of cultivation through the ravages of Panama Disease.

### The Collection, Transport, and Shipment of Fruit.

The first shipment of fruit was made in 1925 to New York and was in the nature of a trial shipment, space being allotted for banana storage in ventilated holds. About 15,000 bunches of various grades were shipped from St. Lucia during this year in excess production over the normal export trade. Owing to the absence of regular fruit boats during this and the following year, much of the fruit was shipped by sloop to Barbados where a somewhat fluctuating market existed.

Definite shipping arrangements were made towards the end of 1926 and a chartered steamship, the *Kong Inge*, made her first shipment in November of that year, a crop of 4,673 bunches being loaded for New York where it passed into the hands of a prominent fruit company. The fruit was collected from the lands of the Banana Company, and from the various depots established throughout the island, where planters disposed of their fruit at the rate of 2*s*. 6*d*. per nine-hand bunch. This entailed a considerable amount of organisation, since time, and the condition of the fruit on delivery, was of major importance.

In all, four shipments of fruit were made by the *Kong Inge* during the next two months, a total of 24,422 bunches being exported. Then followed the unfortunate collapse of the industry due to the promoting Company becoming insolvent.

The total crop of the island at this time was officially estimated to be from 10,500 to 12,500 bunches per month, and this output could have been maintained from March to September of 1927, provided the cultivations continued to receive attention, this failing, the output fell off rapidly and much of the fruit was left to rot owing to the absence of shipping facilities.

### Shipping Problems and Market Reports.

Bananas as shipped on the *Kong Inge* were stored in open holds but protected from the weather, the bunches being placed on end and kept in position by wooden gratings forming a series of sections through the holds.

The atmospheric conditions in the holds varied over a rather wide range as regards humidity, but temperature was fairly constant, as shown in the following details obtained by the recording instruments of the Department.—(*Ann. Rept.*, 1926.)

(1) *Range of Temperature and Humidity in the Banana Holds during the First Trip of the s.s. "Kong Inge," 10th November,* 1926 *to 17th November,* 1926.

| Fore-hold. | | | After-hold. | |
|---|---|---|---|---|
| Date. | Time. | Temperature. ° F. | Relative humidity. m.b. | Max. temperature. ° F. |
| Nov. 10 | 6 p.m. | 75 | 70 (1) | — (1) |
| | 12 p.m. | 77 | 59 | 81 |
| ,, 11 | 12 a.m. | 78 | 59 | 80 |
| | 12 p.m. | 78 | 63 | 78 |
| ,, 12 | 12 a.m. | 79 | 64 | 78 |
| | 12 p.m. | 77 | 56 | 77 |
| ,, 13 | 12 a.m. | 76 | 59 | 76 |
| | 12 p.m. | 75 | 62 | 74 |
| ,, 14 | 12 a.m. | 74 | 55 | 71 |
| | 12 p.m. | 72 | 54 | 73 |
| ,, 15 | 12 a.m. | 72 | 52 | 71 |
| | 12 p.m. | 70 | 50 | 72 |
| ,, 16 | 12 a.m. | 76 | 40 | 70 |
| | 12 p.m. | 55 | — (2) | 55 |
| | — | — | — | 54 (3) |

(2) *Conditions of Shipments of Bananas*, 1916–1927.

| St. Lucia. | New York. | Temperatures in Holds. ° F. Max. | Min. | No. of bunches. | Condition on arrival. |
|---|---|---|---|---|---|
| 10/11/26 | 17/11/26 | 80 | 40 | 4,673 | Moderately ripe. |
| 1/12/26 | 7/12/26 | 82 | 61 | 6,494 | Not ripe. |
| 22/12/26 | 29/12/26 | 79 | 54 | 7,349 | Full ripe. |
| 12/1/27 | 19/1/27 | 77 | 60 | 5,906 | Moderately ripe. |

(1) Loading, open holds and heavy rain falling, departure at 7 p.m. with closed holds.
(2) Holds opened on entering New York harbour.
(3) Final reading with open holds and snow falling.

Under the conditions obtaining in these holds during a voyage of seven days, the fruit was not found to deteriorate unless bruised or over-ripe when shipped.

A shipment of fruit was subsequently made by a local Company formed to dispose of the marketable crop left on the lands of the Banana Company. In this instance the fruit was loaded into closed holds, supplied with forced ventilation by means of fans, after the manner of the modern cargo boat. Following a voyage of about 10 days, the fruit was discharged at New York in a more or less rotten condition. This was a case of decay being accelerated by long confinement in closed holds, from which the carbon di-oxide and the water vapour given off by the fruit, had not been adequately withdrawn.

This venture, therefore, met with no success and was discontinued. Trials of the Bout Rond banana already mentioned had been made previously in conjunction with Gros Michel shipments, but had met with no success, as this variety did not travel well owing to the naturally loose formation of the bunch, and to stem and finger rot to which the Bout Rond is susceptible.

## Termination of Banana Activities and the Present State of the Plantations.

At the time of withdrawing the employed labour of the Banana Company, a considerable area of the cultivation contained untreated plants suffering from Panama Disease. The Agricultural Department was therefore required to carry out the destruction of these plants in order to reduce the amount of infective material, and to prevent the leakage of diseased plants from the abandoned estates.

There remained a large number of Gros Michel free from disease and bearing a crop, and the proceeds obtained from the sale of these bunches to local markets were utilised to defray the expenses of the sanitation work.

On the total withdrawal of supervision, and the non-treatment of new cases of infection arising from remaining stools, the position has markedly changed for the worse, and the writer's conclusion is that no further cultivation of Gros Michel on any but a transitory scale would be possible in St. Lucia under the present methods of large scale cultivation, which consist of nothing more than the attempted evasion

of the disease by reducing sources of infection, rather than the prevention of disease by utilising the soil type which is unfavourable to the spread of disease. There is in St. Lucia at present a sufficient amount of infective material to destroy any ordinary cultivation within a year or so, and any future banana development (in the absence of immune varieties) could consist only of the Short Fig or the Bout Rond, and both of these are unsuited for transport by sea with present methods.

At the present time the greater part of the banana land is covered by a vigorous growth of low bush and shrubs, in close association with excellent stools of Gros Michel which continue to thrive and produce 8 and 9-hand bunches.

Much useful knowledge was gained in the course of the five years' work on bananas, particularly in connection with the soil, and this has a definite value in the development of any other crop under similar conditions. The data collected will be discussed in a future paper on soil changes in relation to tropical agriculture.

With regard to the economic value of the original banana lands, a suggestion is here made that the best areas would serve admirably for coffee development, should any planter be sufficiently hardy to venture thereon.

From the above observations the writer ventures to suggest that more attention should be given to the soil conditions under which bananas thrive, as compared with soil conditions where bananas are largely subject to disease.

The writer wishes to acknowledge the generous assistance of Dr. C. W. Wardlaw, Ph.D., D.Sc., in commenting on the foregoing notes during his tour in St. Lucia as Pathologist appointed by the Empire Marketing Board to investigate Panama Disease.

## Summary.

An account of the origin and growth of the Banana Industry in St. Lucia is given, reference being made to the co-operation of the local Agricultural Department with the developing Banana Company.

The occurrence of Panama Disease, the measures taken against the disease, particularly in selecting only the best planting material, and a survey of the distribution of Panama Disease throughout the Colony is discussed.

Soil conditions as affecting the general health of Gros Michel and variations in disease symptoms are noted.

The collection, shipment, and transport conditions are discussed, and certain suggestions as to future methods of research on Panama Disease based on habitat and ecological factors, conclude the paper.

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THE IMPERIAL COLLEGE OF TROPICAL AGRICULTURE,
TRINIDAD.

*29th April*, 1929.

To the Empire Marketing Board.

Gentlemen,

I have pleasure in forwarding a report of my recent visit to the banana lands of the United Fruit Co., in Costa Rica, Panama, Colombia, and Jamaica.

It is to be regretted that neither Dr. Wardlaw nor I was able to visit the Fruit Company's Research Station at Tela, Honduras, where amongst interesting problems, the important question of the ripening of the Lacatan variety is engaging attention. There seems little doubt that in the search for an immune substitute for the Gros Michel, the Lacatan is the most suitable.

The determination of the precise set of conditions—temperature, humidity, concentration of storage gases, etc.—favourable to successful transport and the subsequent ripening to an attractive colour of a suitable, immune variety is possibly the main aim of the physiologist in the present Research Scheme. Nevertheless several interesting lines of work, to be carried out in close collaboration with my colleague, the pathologist, have suggested themselves in the course of these studies of the Banana in Caribbean plantations.

I have the honour to be, Gentlemen,

Yours respectfully,

LAURENCE P. McGUIRE.

# PANAMA DISEASE OF BANANAS.

REPORT TO THE EMPIRE MARKETING BOARD ON A SCIENTIFIC VISIT TO THE BANANA PLANTATIONS OF COSTA RICA, PANAMA, COLOMBIA AND JAMAICA.

By Laurence P. McGuire, Ph.D., M.Sc., D.I.C.

## INTRODUCTION.

THE following is a report on my recent visit to the banana properties of the United Fruit Company in Costa Rica, Almirante, Colombia and Jamaica.

It will be readily realised that the topography and geology, the climate and soils of these countries show so much variation from area to area that a detailed survey of the whole situation was impracticable. With the exception of the final operation—the actual ripening of the fruit at the port of destination—opportunities for reviewing the many aspects of the industry, commencing with the clearing of virgin forest, have presented themselves. The knowledge of orchard conditions, methods of handling, etc., will serve to direct research on lines applicable to the trade.

The visit, furthermore, has served the useful purpose of enabling one to assess, at value, the gross exaggerations concerning Panama Disease and abandonments. From hearsay alone, one would be led to believe that all wholesale abandonments had been due to a single factor—Panama Disease. This is far from true, and in many cases, as will be seen in the course of this report, this disease has been little more than an accessory cause.

The fact that the incidence of Panama Disease is, as a general rule, greatest in and invariably associated with soils of low fertility, or of obvious adverse conditions suggests strongly the influence of external factors on increased susceptibility ; on the other hand apparently good banana lands, we are told, were wiped out by Panama Disease, implying that Gros Michel, by virtue of its constitution is at all times, in all conditions of health and vigour, susceptible to the virulence of *Fusarium cubense*. Several possibilities are advanced, but as definite records on several points could not be obtained, one is not in a position to assess the correctness of these inferences.

I wish to take this opportunity of placing on record my appreciation of the hospitality shown me by the United Fruit Company, and their assistance to me in my investigations of banana problems. On all Fruit Company Steamers and railways the courtesy of free transportation was extended to me.

In acknowledging my indebtedness, I wish to include whole-heartedly members of the staff of the College. Mr. Geoffrey Evans, C.I.E., M.A., the Principal, has at all times shown a lively interest in all matters relevant to Banana Research: it is largely due to his forethought and action that this extensive and highly educational tour materialised. Professor Briton-Jones, who has had previous experience with Panama Disease and Professor Cheesman who for some time has been pursuing problems of the banana from the stand-point of cytology and genetics, have aided with generous discussion. The information thus afforded proved an exceedingly helpful introduction to the subject before I proceeded to banana cultivations in Central America. Such ready co-operation from members of the staff in the College and the facilities provided for research work there, are to play an important rôle in the attainment of the aims of the banana project of the Empire Marketing Board.

On my return I was able to discuss the situation fully with my colleague, Dr. Wardlaw. Though our visit to the Caribbean banana lands were made quite independently, we were, for the most part in decided agreement not only on banana problems but in matters of general economics and politics. His report is possibly the first to expose fearlessly the current exaggerations regarding Panama Disease and abandonments. Without intending to submit an encomium of him, I have not, for the purposes of due substantiation, hesitated to cite from my notes, points which have already been discussed by him in full.

## COSTA RICA.

Banana cultivation in Costa Rica dates back approximately to the year 1880, but it was not until the year 1892 that the year's export reached a million bunches; in 1908 the ten million mark was reached and for several years approximately nine to ten million were exported annually. Of late there has been a decrease owing to the fact that large areas, originally under bananas, have been abandoned and replanted with cacao or converted into grazing lands.

The Banana estates of Costa Rica are so extensive and soil and climatic conditions so varied that one could not hope to make much more than a general survey in the short time allotted. One was able to visit the best farms and the worst, and a good deal of time was spent in abandoned areas.

In the Siquirres district, I visited one of the Fruit Company's best plantations, Monte Christi, which has been producing consistently excellently for the past twenty years. It was characterised by the uniformly-grown, tall, vigorous plants and a complete absence of gaps ; in between the rows there was very little undergrowth so that cleaning costs were reduced to a minimum. The soil was found to be a free, well-aired, well-drained, dark, sandy loam of good depth. In such a soil the roots, which had developed an abundance of healthy lateral rootlets, were found to have penetrated almost vertically downwards. It is not surprising that loss due to blow-down on this estate is practically negligible, since the texture of the soil is favourable to ready root penetration. This then gave one a clear conception of a very high grade—perhaps ideal—banana soil, which was extremely useful later as a standard of comparison. Another example of a uniformly grown vigorous plantation is the two year old Cedar Valley proposition which will be referred to again later.

In sharp contradistinction to the above was a plantation which the authorities were contemplating abandoning. The plants were smaller, less vigorous in their growth, the leaves rather yellow-green, and there were numerous gaps. The soil, on examination, was a badly aerated, poorly-drained, compact loam. The straggly root system was interesting indeed : root penetration in this soil was obviously difficult and was inclined to the horizontal rather than to the vertically downward growth mentioned above. The lateral roots were not white and turgid, but in many cases blackened and even dead. There was a considerable amount of Panama disease in this area. The above describes fitly the state of affairs frequently found in patches of poorly growing bananas in otherwise good plantations.

Numerous plantations were visited, examinations of the soil conditions made and various types intermediate between, and resembling the above, were encountered. In some of the better areas the naturally fertile soil is periodically enriched by the deposition of alluvium and thus high productivity has been maintained throughout

the history of such plantations, and in the absence of unforeseen circumstances, it may reasonably be hoped that these will continue to be excellent banana lands. Other areas, not so fortunately situated, are capable of producing well for the first few years, after which gradual degeneration follows. Under the present agricultural practice, these areas provide food for pessimistic speculation. The question of husbanding the natural resources of the soil is indeed serious, and has not received the prominence and attention due to it. Even a little treatment—breaking up of the soil for aeration, improvement of drainage, an occasional re-planting, the choice of a suitable rotation crop—would surely prove beneficial. Economic conditions are such that it is more profitable to exploit new lands than to improve the existing plantations.

During my stay, a number of abandoned areas were visited. Records of precise cause of abandonments were unfortunately not available. In addition to the ravages of Panama Disease, there are numerous other causes as will be readily appreciated after considering the following observations. One particular area, originally under bananas had been replanted with cacao and has since been abandoned. These trees produced practically nothing and were most unhealthy. Judging by the colour of the leaves, they were obviously suffering from acute chlorosis. This area, situated quite near Matina River, is badly flooded periodically. It is probable that the soil undergoes, at these times, a thorough leaching-out. Another area in which the Gros Michel had fared badly had been replanted with the Lacatan variety ; from their unhealthy condition it would appear that this area was a low grade banana soil. It should be mentioned that this area had been riddled with Panama Disease ; as the Lacatan has been definitely proved immune, conclusions may be drawn as to the part played by unfavourable conditions in facilitating the spread of disease.

Labour in the Latin-American republics is an extremely expensive item which is responsible for the reduction to the minimum cleaning, draining, operating and general upkeep.

On soils unsuitable for vigorous growth of the banana plant one invariably finds active competitive growth of secondary bush and grass necessitating more frequent cutlassing, which is reflected in the maintenance costs.

Again there are abandoned areas in which the lack of efficient drainage was clearly evident ; in both Costa Rica and Panama

compact loams are frequently met with and it seems the upkeep of main and lateral drains has been neglected presumably because production returns did not allow the expense of such operations. In short, failure to reflect the necessary margin of profit is the deciding factor in abandonment, and the chief causes of such failure are Panama disease, high maintenance costs and low productivity due to adverse soil conditions.

With regard to the incidence of Panama disease, it is said that there is not a single farm on which it does not occur to varying extents. As a general rule, cases were more numerous where plants were less vigorous. Cacao Farms in the Zent district present an interesting problem in this connection. Years ago these farms were completely wiped out by Panama disease and have since been converted chiefly into cacao lands. On examination of the soil, the usual adverse conditions, referred to above, were not in evidence and one would be inclined to regard this as good banana land on which vigorous growth would be assured. To what then was this failure to be ascribed ? In the first place no results of detailed chemical analyses were obtainable—it is possible that such analyses would have offered a solution to the problem. In the second place when large areas were being opened up there was naturally a demand for large quantities of planting material, which was under the circumstances perhaps not so carefully selected : it is possible that diseased suckers were used and these lands infected in consequence. It is most unfortunate that no definite reliable information on the above two points can be obtained, since it would help us to answer an important question. Is *Fusarium cubense* so virulent a parasite that the Gros Michel plant, no matter how robust and vigorous, is susceptible ? A substantially corroborated answer in the negative would infer that improvement of deteriorating soils would help to stem the invasion of Panama disease. In the present state of knowledge the question remains unanswered. Abandoned areas have been brought back successfully into banana cultivation, and it would be interesting to know how successful such a project would be on this plantation.

The two year old Cedar Valley banana plantation on a flat alluvial plain was another example of uniform growth of robust plants producing well. A few isolated cases of Panama disease were present. The precise nature of infection of one individual, surrounded by numerous healthy vigorous plants, is indeed an enigma !

Cases are numerous where plants surrounding a diseased stool have remained for years free of disease. In fact in no observed case had infection spread radially from a central point affecting neighbouring stools first.

I then proceeded to other lands in the Bananito district where the soil was very varied, consisting of river deposits with an admixture of varying percentages of clay washings from the hillsides. Several good banana areas were to be seen here. On a plot, near the river, the advantage of shovel cleaning was being tried out. The ground was shovelled clear of all weeds and grass which were heaped between the rows. Banana growth was vigorous and the production of good fruit was high, pointing to the beneficial effect of such cleaning. It should be pointed out, however, that the soil was naturally rich and drainage good. Despite the general vigorous growth, Panama disease was present.

Experimental plots in this district were visited : it should be mentioned that these are not under the supervision of the Fruit Company's Research Staff.

On a strip of water-logged soil on the farm Pleiades where the leaves had " yellowed " a plot of one acre was heavily pruned, the undergrowth cleared and drains cut with obviously good results.

In another area fertiliser experiments were in progress but up to that time no conclusions could be drawn.

A plot of one and a quarter acres which had been completely cleared, old stools dug up, and replanted in Colombian style, was being compared with an adjacent plot of the same size which was merely receiving the customary Costa Rican treatment. Records were kept of the number of marketable bunches from each plot. The replanted plot showed the greater number to date. Following on a visit from one of the Colombian employees, the experiment was undertaken merely to see whether increased profits would accrue from adopting the Colombian method of planting. It is a pity that a third plot, cleaned and old stools dug up, had not been replanted in Costa Rican style. Much light might have been shed on the value of replanting. The " digging out " in itself would make for conditions of improved aeration.

It should be explained that in the Colombian style of replanting, the base of the old parent (or " head "), together with three or four

suckers is removed *en bloc* and replanted; in the Costa Rican, however, heads are dug up and chopped into " bits " weighing five to eight pounds, and containing at least three good suckers.

Abandoned lands in this district have been replanted with cacao or converted into grazing grounds, but it is interesting that some of these lands have again been converted into banana plantations with no small measure of success. The Red Banana has been cultivated on disease-riddled areas and has been found to succumb in many cases. Since this variety is normally extremely resistant, to what factors, presumably external, are we to ascribe this increased susceptibility ?

In addition to Panama disease, two further physiological banana troubles were encountered :—

(i) Leaf scorch in the Red Banana.

(ii) The Talia disease (named after the farm on which it was first reported). This appears to be a case of internal breakdown in the fruit itself, and I understand, without cutting open the fruit, its presence is detectable only in the mature fruit at an advanced stage. No organism has been isolated and little interest has been aroused on account of its infrequent occurrence and restricted distribution.

Records of chemical analyses of the soil in different areas were not available. The presence of adequate quantities of lime in the soil is regarded as having a deterrent action on Panama disease—the fact seems borne out by the relatively low occurrence of the disease in plantations near the rivers Reventazon and Barbillo, which flow through calcareous formations. However, other factors may account for this comparative freedom from disease.

In commenting on the backwardness of agriculture in Costa Rica and the absence of ordinary agricultural practices, a description of the method of opening up new areas is perhaps apposite. The new area is surveyed, the underbush cleared and stakes placed in rows. Holes fifteen inches in diameter and fifteen inches deep are dug at the stakes, and the planting material, or " bits " as they are called, are planted. The large trees are then cut down and after a while the young banana plants emerge through the mass of decaying branches, trunks, etc. No attempt at forking or stirring the soil is made; the plant must make the best of the small hole in which it has been placed.

*Summary of Visit to Costa Rica.*—(1) The Banana propositions in Costa Rica are such that in the short space of time allotted for the visit, little more than a general survey could be effected.

(2) The expression " wholesale abandonment due to the ravages of Panama disease " needs modification. In the absence of definite records and information as to the precise reasons for abandonment, I submit that failure to reflect the necessary margin of profit has been the deciding factor and such failure has been due to one or more of the following :—

(*a*) Panama Disease.

(*b*) Low Production due to adverse soil conditions (poor aeration, poor drainage and water-soak, etc.), and lack of upkeep.

(*c*) High Maintenance Costs. These would be higher in poorer banana soils where competitive growth of secondary bush and grass is more active.

(3) Panama disease is indeed widespread and it is stated there is hardly a farm on which it does not occur to varying extents. In no observed case had infection spread radially from a central point affecting the adjacent stools first. Why apparently good banana soils have been ravaged with Panama Disease is in the present stage of knowledge unanswerable and one can but offer theories. Definite records of the history and development of individual farms, of the sources of planting material, especially when large areas were being pressed into service, and of detailed chemical analyses of soil samples are entirely non-existent.

(4) Banana cultivation in Costa Rica implies merely the utilisation of the natural fertility of the soil ; it is feared the extremely high cost of labour will postpone the day of detailed agricultural practices.

## PANAMA DIVISION.

Large scale banana operations in the Panama division commenced approximately 30 years ago and were centred around Almirante in Northern Panama. Of late years consequent on the scarcity of fruit and the necessity for exploitation of new areas, banana lands were opened up in the Canal Zone, while the Chiriqui division on the Pacific side of the Isthmus is now in course of being established. The two newer divisions were not included in my itinerary : my remarks are therefore confined to my visit to the Almirante Division,

which consists of three districts, viz., the Changuinola, the Sixaola (named after the two large rivers) and a newer extension, the Talamanca. I was able to see very little of the last named owing to a wash-away. It should be mentioned that the cost of upkeep of railroad tracks and bridges is exceptionally high owing to the torrential nature of the seasonal inundations to which this country is subjected.

Panama disease was first reported in 1903, and during the last ten years abandonments have been necessitated to an amazing extent. To the man in the street this is, of course, all due to Panama disease. From a consideration of the following it will be realised that, as in Costa Rica, several contributory causes have played equally prominent parts. Definite information on many questions of past history, etc., were very difficult to obtain. It appears that most of these areas produced well at the start and for several years high production was maintained. While Panama disease was reported early in the history of these farms, it was not until the later years that rapid spread was recorded. In other words, while the soil was sufficiently rich to allow of vigorous growth and high production, the spread was often very slow; later when the soil had degenerated and less vigorous growth was possible, the spread is reported as having been appreciably more rapid. Again, therefore, one's attention is drawn to the impoverishing influence of a continuous single crop on virgin soils. Some soils have continued to produce good fruit consistently over a long period, while others, after five, ten or fifteen years, in the absence of any attempt at conserving the natural fertility of these soils by ordinary agricultural treatment, have deteriorated to an extent that has rendered further maintenance unprofitable.

In considering the natural spread of the disease there seems little doubt that during extensive expansion with consequent demand for large quantities of planting material, diseased suckers were used. Again too, in this rush, the survey of proposed new banana lands could not be undertaken with sufficient attention to detail: in consequence land totally unfit for banana cultivation was pressed into service. An abandoned area which had been replanted with the Lacatan variety bears ample testimony. Growth was extraordinarily backward, and on examination of the soil it was found that below a shallow surface soil of some six inches of compact loam, there was a layer of thick sticky yellow clay of low permeability, in which root penetration would be difficult and drainage obviously poor.

My chief interest in the Panama division was Farm 6 in the Changuinola district, where I spent most of the time with the Fruit Company's geneticist. On this farm a large collection of banana and plantain varieties has been made with a view to breeding an immune hybrid to replace the Gros Michel. (Full descriptions of these varieties are already in print so that they will not be discussed in this report.) A tremendous amount of work has been done here, but unfortunately, owing to the prevalence of Panama disease, the Gros Michel cannot be used as either staminal or ovarial parent. In consequence, varieties, which of themselves have but few desirable characters, have perforce to be used as parents. Up to the present no hybrid of commercial value has been obtained.

The stay here was extremely important as one had an opportunity for studying these varieties growing under comparatively similar conditions. One of the chief aims of the present research scheme, from the Physiologist's point of view, is the choice of a suitable substitute for the Gros Michel, after which research will be conducted with a view to ascertaining the precise set of conditions under which transport and subsequent ripening up to an attractive colour can be effected. The more nearly these conditions approximate to Gros Michel conditions the better are the chances of persuading the trade to take up the new variety. There seems but one variety about which optimistic views may be entertained, viz., the Lacatan. Ripening experiments with this variety are now in progress at Tela. I understand this fruit has, on occasions, ripened satisfactorily, so that in course of time this problem will no doubt be solved. The Lacatan is a banana of good bunch habit, excellent flavour and delicate texture. It would, however, require far more attention in the field.

The general regularity of the bunch is often interfered with by the lower leaf on the side next the bunch. As the bunch develops, this leaf is held between successive " hands," and often in the reaping bad bruising results. In the Gros Michel this leaf is not persistent. It may be observed growing between successive hands while the bunch is still very young, but with advancing maturity this leaf withers and falls away. Many varieties are like the Lacatan in this respect. The Lacatan is, moreover, not inclined to deep rooting so that in areas where conditions militate against root penetration this variety would be very subject to blow down. The weight of the bunch was frequently perceived to have pulled down the whole plant which was either completely uprooted or its trunk snapped off at ground level.

This collection of banana, plantain, and abaca varieties has been derived from more or less world-wide sources : in most cases they have grown far more vigorously and borne bunches of greater size (more numerous " hands " and larger " fingers ") than in their original haunts. So that this area is to be regarded as good banana land. In this highly infected soil, in which naturally the chances of infection are correspondingly high, the behaviour of the highly susceptible varieties, e.g., Gros Michel and indio-plantain, which are usually extremely short-lived, when compared with the behaviour of the highly resistant and immune varieties, stresses the importance of inherent constitutional characteristics in the matter of resistance and immunity.

Abandoned areas have, as a general rule, been replanted with cacao or coconuts or turned into grazing lands. The cacao has so far not come up to expectations, while the coconuts cannot be regarded as successful. In general, growth is poor and they are subject to various troubles. About 4,000 acres of Lacatan have been planted, but these are not being exported in any quantity yet. In passing through the plantations, the irregularity of growth and the great variability of the soil are striking. The Changuinola and Sixaola districts may be described as extensive, for the most part flat alluvial plains which have been laid down by large rivers, which have repeatedly changed their course. Leaching by periodical flooding and high rainfall has contributed further to the general variability. These plains are frequently interrupted by rivers, creeks, lagoons, swamps, etc. Bananas growing near these swamps exhibit in general the effects of water-soak, which has no doubt been responsible for poor productivity and subsequent abandonment of large areas.

On another area, production was reported as having been good for four or five years, after which a progressive falling-off set in culminating in abandonment. In the later years Panama disease had spread rapidly and, of course, is put down as the cause of abandonment. Nevertheless, examination of soil conditions at several points reveals numerous adverse conditions : the surface was shallow and compact, below which was a deep impervious sub-soil of sticky clay in which root penetration would be difficult, and drainage and ventilation quite inadequate.

My visit to the Almirante division may be summarised thus :—

(i) Attention is again drawn to the deterioration of virgin soils under a continuous single crop, when the ordinary methods of agricultural treatment, for purposes of conserving original fertility, are not practised.

(ii) Careful analysis of the position shows that there are numerous factors in addition to Panama disease, to which abandonment may be attributed.

(iii) In general the spread of Panama disease was slow in the early history of plantations when virgin conditions made for vigorous growth of the Gros Michel.

(iv) An opportunity was taken of comparing the bunch habit of numerous varieties of bananas. In the search for an immune variety as a substitute for the Gros Michel, the Lacatan seems most suitable.

(v) The extraordinarily vigorous growth and high productivity of the numerous imported resistant varieties in badly infected soil stresses the importance of inherent constitutional characteristics in questions of resistance and immunity to Panama disease.

## COLOMBIA.

Records show that Bananas were first exported from Colombia in 1892. In 1911 nearly five million bunches were shipped and in 1926 the ten million mark was reached. Last year, despite the strike among Fruit Company labourers, it was estimated that this figure would be reached.

Colombia is full of interest to any one engaged in investigating Banana problems on several grounds :—

(i) No occurrence of Panama disease has yet been reported there. The study of the effects of water-soak, lack of aeration and general adverse factors responsible for abandonment, is thus facilitated.

(ii) Owing to low rainfall and seasonal dry periods irrigation is necessary. The study of the water relations of the banana plant is suggested as a line of work in connection with Panama disease.

The banana lands of the Santa Marta division consist of a large coastal plain deposited by several parallel rivers, chiefly the Rio Frio, Sevilla and Aracataca, which rise in the Sierra Nevada. These

soils exhibit considerable variability and it was interesting to note that the Gros Michel was established, and thriving, on numerous types of soil varying from coarse sands to fine clay loams.

Despite the absence of Panama disease large areas have been abandoned. In the Rio Frio district, near the sea, large areas have been abandoned on account of "salting up." These are low-lying areas and, at present, the only vegetation consists of leathery-leaved xerophytes and the samphire, a remarkably reliable plant indicator which thrives only on soils of high saline content. Examination of the surface soil shows a large percentage of soluble crystalline matter which has not been leached out owing to the inadequacy of the supply of irrigation water and the high evaporation in these parts.

On large areas where the soil is of open coarse texture the Gros Michel plantations are of a high standard of excellence; so long as an adequate supply of irrigation water is available, particularly in the dry periods, the high productivity of these plantations seems assured. There are, on the other hand, areas in which conditions do not make for good drainage and proper soil aeration. Examination of the soil has frequently revealed the presence of a deep stratum of blue, or blue mottled with red, clay, below a shallow surface soil of perhaps nine to twelve inches deep.

In planting up this land, the customary fifteen inch hole is dug at intervals of eleven feet by eleven feet, so that from the beginning the rooting system is in contact with this impervious layer of clay. The toxic action of such layer is clearly evident in the blackened (often killed) flaccid rootlets and the general stunting of growth. I understand it is not unusual, in these circumstances, for the plant to take as long as eighteen to twenty months, instead of about twelve months, to produce fruit suitable for harvesting. General preparation of these areas before planting with a view to improved ventilation would most probably go hand-in-hand with increased productivity.

The effect of water soak—an important cause of abandonment in Colombia—may be studied the more easily as graduations from the thoroughly water-logged to the well-drained, open condition can be found within comparatively small areas. One particular case in which bananas were growing in and on the sides of a water-logged depression was striking indeed. As one walked down the incline there was a progressive stunting of growth of the whole plant and an increasing paling of the greenness of the leaves to a yellow condition.

It is interesting that in many cases, especially where the underlying adverse factor is obvious, reclamation of abandoned areas has been possible. In the case of water-logged areas, deep main and lateral drains have been mechanically cut by means of the drag-line and the water table lowered in this way.

A most serious source of loss in Colombia is the " blow down." Wind-storms arising in the hills sweep down the plains and cause severe losses. Total uprooting of the whole plant is, despite the fury of these storms, by no means the general rule, especially where soil conditions are favourable to deep root penetration. In Jamaica, pruning operations are carried out in such a way that over 90 per cent. of the year's fruit is reaped before the " blow " season. Replanting operations, too, are timed with this object in view.

The attractiveness of the fruit is often interfered with by the activities of the Banana beetle (*Colaspis hypochlora*, Lefevre, 1878), which has been nicknamed the " Chinese Secretary " on account of its weird markings, suggesting Chinese characters, which it makes on the skin of the fruit. It does not, however, completely puncture the skin of the fruit as does the Banana Bee (*Trigona amalthea*, Oliv.) which in this respect is more serious. These insects are engaging the attention of the Fruit Company's entomologist.

While in Colombia, I had the good fortune to meet Dr. A. O. Reinking and Mr. Slocum of the Company's Research Staff. I had, therefore, an opportunity of discussing with them various banana problems and proposed lines of work. I am indebted to both of them for much sound information.

*Summary.*—(i) Colombia occupies a unique position among the world's banana producing countries in that, at no time, has Panama disease ever been reported.

(ii) The chief causes of abandonment have been poor drainage, poor aeration, " salting up " and inadequacy of supply of irrigation water.

(iii) A most serious cause of loss yearly is the " blow down " due to wind storms arising in the hills.

(iv) Owing to low rainfall and seasonal dry periods, irrigation is compulsory.

# JAMAICA.

The visit to Jamaica was not originally included in my itinerary. In view of the Colombian strike, the Elders and Fyffes boats, normally due to call at Santa Marta, were being diverted. Instead of making a prolonged stay in Colombia, which this would have involved, I was able, through the courtesy of Mr. Bradshaw, the Manager of the Santa Marta Division, to proceed to Jamaica to meet the boat. I was thus afforded an opportunity for reviewing the situation there. I should mention that Mr. Hartley Rowe, one of the Vice Presidents of the Company, who was in Jamaica in connection with the purchase of the Lindo Estates, very kindly authorised my visiting the Research Division in Honduras. As several matters concerning our cold storage station required my personal attention, my immediate return was deemed advisable. It is to be regretted that neither Dr. Wardlaw nor I was able to make this important visit.

The banana producing centres of Jamaica may be roughly classified into two :—

In the South Eastern and South around St. Catherine and Vere are large flats, where rainfall is restricted (approximately 30 inches and 20 inches respectively), and irrigation is necessary ; in sharp contrast, the hilly districts of Portland, of considerably higher rainfall (130 inches approximately), do not require irrigation. In the former there is considerably less Panama disease, suggesting again the possible importance of a study of the water relations of the banana plant as an avenue of approach to successful results in Panama disease Research.

Examination of the soil conditions, texture, drainage, aeration, etc., in these areas stresses the influence of external conditions in the spread of the disease ; it further points out the extremely wide range of soils on which the banana may be profitably cultivated. Two particular farms were strikingly interesting in this respect. In one the surface soil could be described as a seam, at least four feet deep, of coarse sand or fine gravel, and the other was a sandy soil containing as much as thirty per cent. of limestone, chiefly in small lumps. I was told that these farms were regarded as producing up to the average, though naturally the supply of irrigation water was high. An interesting attempt at growing bananas on a neutral soil of sixty per cent. clay of low permeability was in progress. Drains four feet six inches deep, were cut for every two rows of bananas

so that each row was marginal on a drain. At the time of my visit the plants looked comparatively healthy. Unfortunately, however, the upkeep was expensive, apart from damage done to the roots by the cracking of the clay. As there are large areas of this type of soil available, the question of introducing clay-tile drainage on a small experimental plot is being considered, though it is realised that initial costs would be high. Good production, if maintained over a number of years, would justify the venture.

I was able, on two occasions, to accompany Dr. Klevenger, the Fruit Company's soil expert, who had come to Jamaica to carry out reconnaissance expeditions on the lands, newly acquired under the purchase of the Lindo Estates.

As Fawcett in his book "The Banana," describes in detail the intensive cultivation, land preparation, rotation crop, irrigation and contour drainage and the many aspects of the Jamaican Banana industry repetition seems unnecessary here. Furthermore, I shall not discuss the present quarantine regulations and the nine-root treatment in Jamaica as my colleague has dealt with the matter at length.

## SUMMARY AND CONCLUSIONS.

While the shortness of the time allotted for the visits to the banana producing countries has precluded detailed survey of the whole situation, it is, nevertheless, possible to generalise on several interesting points.

Agriculture in the Central American republics is still a process of exploitation of the natural resources of the soil: no detailed agricultural methods are practised. On certain alluvial areas, particularly those enriched with a periodical deposition of silt, high production has been maintained over a considerable number of years, but on others this has been far from the case. In short the soil, under a continuous single crop in the absence of any attempt to conserve natural fertility, seems to have undergone, with consequent fall in production, a progressive deterioration towards the inevitable abandonment.

The high cost of labour has made it more profitable to exploit new areas rather than improve the existing farms. With the march of time, however, economic conditions may turn the scales so that

reclamation of the abandoned areas will be preferable to the acquisition of new lands. Abandoned lands have already been replanted with success.

In the rush to open up new lands it is possible that the survey was not always carried out sufficiently carefully, with the result that lands quite unsuited to bananas were pressed into service : the prevailing assumption that virgin soil is, of necessity, always fertile is quite unwarranted—a fact borne out by irregularity of growth, even within small areas of newly opened land, where due care has been taken in the selection of vigorous planting material.

Examinations of soil profiles in both abandoned lands and in bad patches in otherwise good plantations often reveal a surface soil of varying compactness under which is a stratum of sticky clay of low permeability, in which root penetration is difficult. Water-logging and poor aeration have obviously militated against successful growth and production to an extent that has necessitated abandonment.

Enough has been said to disprove the current erroneous views regarding Panama disease in abandonment. It has undoubtedly been most important, but in many cases it has been only an accessory factor. Large areas have been abandoned in Colombia where Panama disease has not yet been recorded ; in view of this, the importance of other factors which we may describe broadly as adverse factors, may be more readily appreciated. These include :—

(*a*) Progressive deterioration of soils, once suitable for vigorous growth.

(*b*) Adverse soil conditions, several of which are, to a certain extent, inter-related, e.g., poor drainage, defective aeration, impermeability and/or toxicity of sub-soil, shallowness and/or compactness of surface soil, high acidity, high salinity, inadequacy of water supply for irrigation, leaching out by floods or high rainfall.

(*c*) Lack of upkeep. Where adverse conditions prevent vigorous growth in the banana, competitive growth of secondary bush, grass, etc., is increased and is reflected in increased cleaning costs.

Any of these factors individually or collectively may cause abandonment.

Panama disease is reported to have spread most rapidly in areas where adverse soil conditions militate against healthy vigorous growth ; on the other hand, resistant and immune varieties planted on highly infected soils have shown remarkable vigour. We have thus support for two views, which in the light of present knowledge, appear conflicting. The former suggests that the Gros Michel, in the state of low vitality induced by unfavourable conditions is then unable to check the invasion of *Fusarium cubense ;* the latter implies that at all times, in all conditions of soil and in all conditions of health and vigour, the Gros Michel by virtue of inherent constitutional characteristics is susceptible to the virulent invader. There is much to be said in support of both views.

" Blow-down " in the windy season is a source of considerable damage. In Jamaica, planting (and replanting) and pruning operations are timed to ensure that over ninety per cent. of the year's crop is reaped before the windy season (August–October).

In the course of this report I have refrained from discussing the strike in Colombia, or expressing any views of the political situation there, or in any other Central American republics. Political interests and the wide field for economic study merit the attention of a suitably trained economist.

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